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ACADEMY of HEALTH SCIENCES, US ARMY

FORT SAM HOUSTON, TEXAS 78234

MEDICAL ASPECTS OF NUCLEAR WEAPONS

AND THEIR EFFECTS ON

MEDICAL OPERATIONS

SUBCOURSE MED447

JUNE 1990

DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

The education specialist responsible for revision of this edition was James F. Legendre, AUTOVON 471-3873 or commercial phone (512) 221-3873; Commandant, Academy of Health Sciences, ATTN: HSHA-TCC, Fort Sam Houston,Texas 78234-6100.

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The editorial assistant for this edition of the subcourse was John L. McIntosh.

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CORRESPONDENCE COURSE OF
THE ACADEMY OF HEALTH SCIENCES, U.S. ARMY

SUBCOURSE MED447

MEDICAL ASPECTS OF NUCLEAR WEAPONS AND THEIR EFFECTS ON MEDICAL OPERATIONS

INTRODUCTION

Nuclear weapons may have a tremendously devastating effect, but by no means are they the ultimate in weapons. In fact, much can be done to defend against these weapons and still maintain some ability to continue military as well as national operational functions. Of course, this is more true for those effects which we have classified and you know as residual, when compared to the immediate or prompt effects. Survival of large population segments, which have survived the prompt effects, can be ensured by proper shelter from fallout or the residual effects. Because the post-attack environment requires an aspect of nuclear medical responsibility be employed in medical services and the other residual reserves to obtain optimum results, a knowledge of the operational characteristics and post-attack tasks must be absorbed prior to the event and capabilities developed and exercised for medical support.

On the integrated battlefield, the Army Medical Department will be expected to continue medical support operations and to treat large numbers of nuclear casualties despite the enormous capabilities of nuclear weapons to wreak havoc upon and within military units and personnel. This expectation alone forebodes a tremendous undertaking. In addition, attention must be given to another aspect of the nuclear medical responsibility, which, in the final analysis, may be every bit as important a contribution to the support of the Army's combat mission. This is the time-honored responsibility of the medical officer for advising the commander on all medical problems pertaining to the health of his command.

Ionizing radiation is important to the military commander because of its effect on people. This means that the commander should, does, and will look to his surgeon for advice on the effects of radiation exposure. But because of the insidious nature of these radiation effects, and limitations in the present knowledge of radiation effects and associated technology, radiation guidance becomes an exceedingly challenging responsibility for the surgeon and his staff.

Conservation of manpower, without question, will be of great concern in any mass casualty situation, and especially so, in a nuclear situation. The basic problem that the medical service faces in planning for mass casualty situations is not the type of injuries to be expected, or a lack of experience, or dispersion of the units, but rather the large numbers of casualties requiring treatment that will occur at almost the same instant. One phase of the problem visualized at this time is the training of the individual soldier to take care of himself (self-aid) and of his associates (buddy-aid) until medical assistance can be made available. Another phase of the problem lies

in the decisions made by the commander in his consideration of the casualties and the tactical situation. The commander must constantly weigh the ever increasing health hazards against the demands of the tactical situation. This is a difficult problem for any commander but the more he knows and has thought of his potential problems in a possible mass casualty situation, the better his decisions will be when faced with the actual situation.

This subcourse is directed toward the medical effects of nuclear weapons; command guidance on irradiated personnel; medical management of mass casualties with a view toward minimizing manpower damage and preventing unnecessary loss of personnel capable of continuing their military mission; effective command, control, and employment of medical units in the post-attack environment; and actions to be taken by the military, in this case, specifically the medical units, in order to preclude and defend against the tremendous residual effects of nuclear warfare. The ability to perform under such conditions can be attained through effective command, control, and employment of the medical units after the nuclear explosion.

This subcourse consists of 5 lessons and an examination. The lessons are:

Lesson 1, Review of Nuclear Weapon Effects.

Lesson 2, Ionizing Radiation Injury.

Lesson 3, Comparative Effects of Nuclear Weapons; Residual Radiation Dose and Decay Calculations; and Management of Mass Casualties.

Lesson 4, Command Guidance on Irradiated Personnel and Nuclear Accidents and Incidents.

Lesson 5, Medical Operations in Fallout.

Examination

You will be awarded 21 credit hours for the successful completion of this subcourse.

Text and materials furnished:

Subcourse MED447, May 1990.

Map Helotes, 1:50,000, Sheet 6243 II, series V782, Edition 1-DMATC, Stock No. V782X62532.

Overlay, Simplified Fallout Predictor.

Calculator Set, Radiac, ABC-M1 (printed on inside of rear cover).

No other materials are required.

YOU MAY RETAIN THE STUDY MATERIALS.

No mail-in answer sheets are provided for the lessons in this subcourse because you are to grade your own lessons. The lesson exercises and solutions for all lessons are contained in this booklet. You are encouraged to complete the subcourse lesson-by-lesson.

You will submit your examination answer sheet to the Academy for grading.

WE SUGGEST THAT YOU FOLLOW THESE STUDY PROCEDURES:

—Read and study each lesson assignment carefully.

—**REFER TO THE GLOSSARY EXPLAINING THE MANY ACRONYMS AND SPECIFIC TERMS FOUND THROUGHOUT THE LESSONS.**

—Read again through the text material, completing unanswered exercises and correcting others as needed.

—When you have completed the exercises to your satisfaction, compare your answers to the ones on the solution sheet located at the end of the lesson. Check the references for your incorrect answers.

—After you have successfully completed one lesson go on to the next and repeat the above procedures.

—Complete the examination answer sheet and mail it to us for grading. The grade you make on the examination will be your rating for the subcourse.

—No postage is required.

A Student Comment Sheet is located in the back of this booklet. It is to be returned with your examination answer sheet. As you study the subcourse you may wish to make notes of suggestions or criticisms and write them on the comment sheet after you have completed the examination.

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LESSON ASSIGNMENT SHEET

LESSON 1	--Review of Nuclear Weapon Effects.
LESSON ASSIGNMENT	--Paragraphs 1-1--1-22.
MATERIALS REQUIRED	--None.
LESSON OBJECTIVES	--After completing this lesson, you should be able to:

1-1. Describe a brief history of the development of the nuclear bomb.

1-2. Discuss the principles of a nuclear detonation.

1-3. Describe blast, thermal, initial radiation, and residual ionizing radiation.

SUGGESTION --After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 1

REVIEW OF NUCLEAR WEAPON EFFECTS

Section I. PRINCIPLES OF NUCLEAR WEAPONS

1–1. DEVELOPMENT OF NUCLEAR WEAPONS

As an introduction to nuclear weapons and their effects, it is most interesting to consider the succession of small, but yet significant, discoveries in nuclear physics which contributed toward the initial nuclear detonation at Trinity Site, Alamogordo, New Mexico. For this story, one might conceivably begin back about 2,000 years ago when Democritus taught that all matter consisted of tiny indivisible particles called atoms, or atomos, meaning indivisible.

a. The most significant contribution during the 19th century occurred in 1896 when nuclear radiation was discovered by Antoine Henri Becquerel while he was using uranium oxide and photographic plates; but, most of the specific work in nuclear physics was done in the 20th century. One could say that it all started in 1905 when Einstein proposed the theory that energy and mass were convertible and related by the formula $E = mc^2$. In 1910, Ernest Rutherford discovered the alpha particle. In 1931, Sir James Chadwick, who was later to head the British Atomic Mission to the United States, discovered the neutron when he bombarded beryllium with the alpha particle discovered by Rutherford. In 1934, Enrico Fermi, while bombarding uranium atoms with the newly discovered neutron of Chadwick, unknowingly split the atom producing the first artificial transmutation. Also, that year Professor Harold Urey won the Nobel Prize in chemistry for his isolation of heavy hydrogen which is important to the fusion process in thermonuclear weapons. In 1935, Dr. Niels Bohr won the Nobel Prize in physics for postulating the internal configuration of the atom.

b. It is interesting to speculate on the probable success of the Germans in their development of a nuclear weapon had not their political doctrines intervened. Of particular note was the case of Dr. Lise Meitner, who, while working with the German physicists Hahn and Strausmann at the Kaiser Wilhelm Institute, explained the phenomenon of Dr. Fermi's experiments of the fissioning of the uranium atom. Had she been able to explore and convey to the German government at this time the significance of the experiments, the final outcome of the war may have been changed. But she fled Nazi Germany after learning of Heinrich Himmler's exclusion act because she was Jewish. Later, Otto Hahn won a Nobel Prize in chemistry for enlargements on her work.

c. In 1939, Dr. Fermi, while working at Columbia University, after fleeing his native Italy because of possible retaliation for his antifascist views, went to the United States military to explain the possibility of the new explosive power he now understood to be released in the process of fissioning. But at this time this concept was something out of "Twilight Zone," and he got the reply "don't call us, we'll call you." Later that year

Alexander Sachs carried a letter, composed by Albert Einstein and formulated by a group of scientists knowledgeable in the weapon's potential of the scientific discovery, to President Franklin D. Roosevelt. However, several precious months were lost while Sachs waited to gain admission to Roosevelt's office. In all America at this time, there was less than one ounce of metallic uranium. Also, even at this early development stage, Russia picked up the wind of the possibility of the production of such an "atomic bomb."

d. In August 1940, Edgar Sengier, director of Belgium's uranium mines located in the Belgian Congo, contemplated his country's control by the Nazis and quietly shipped 1,200 tons of high grade uranium in 2,000 steel drums to Staten Island, New York. The U.S. authorities were notified but the records were mislaid, and for two years the uranium lay undiscovered in a Staten Island warehouse.

e. In 1941, at a top level committee meeting, Dr. Kenneth Bainbridge, a Harvard physics professor, discussed the possibility of military application of a uranium detonation. But late in the year no chain reaction had been made, no appreciable amount of ^{235}U had been separated from the more abundant ^{238}U, and only minute amounts of plutonium had been produced by Dr. Glenn Seaborg of the University of California. However, during the year, the first controlled chain reaction was produced by Dr. Fermi in the Stagg Field stadium stands at the University of Chicago. In December, Dr. Vannevar Bush, head of the Office of Scientific Research and Development, was appointed to determine the feasibility of making such a nuclear weapon.

f. In August 1942, the Manhattan Engineering District was formally established. In September, Colonel Leslie Richard Groves took over the newly designated Manhattan Engineering project. Colonel Groves was a graduate of West Point, the Command and General Staff School, and the Army War College. He had served as deputy chief of construction in building the Pentagon, and he was promoted to the grade of brigadier general on 6 September 1942. One of Colonel Groves' deputies located the 1,200 tons of uranium ore at Staten Island. Colonel Groves hired Dr. Robert Oppenheimer to be his deputy and to direct the laboratories that were to build the bomb. Though $100 million was initially allocated for the weapon's production, this was to grow into $2.3 billion. During this time it was decided that Oak Ridge, using the gaseous diffusion process, would produce the ^{235}U needed for the gun assembly weapon while the Hanford, Washington, plant would use the Seaborg process to produce plutonium.

g. In August, 1943, Roosevelt and Churchill signed an agreement for British scientists to work at Los Alamos and Oak Ridge, with the U.S. accepting British security clearances. Among them was Dr. Klaus Fuchs, a German who had joined a Communist youth organization in the early 1930's and subsequently was beaten up at a Nazi youth rally during the Nazi takeover of Germany. This had reinforced his Communist sympathies. He later received doctorates in both mathematics and science from Bristol and Edinburg Universities. While in Canada, he was interned as a hostile alien, but he returned to England in 1942 and taught at the University of Glasgow. In December, 1943, he joined his British colleagues in the U.S. Even at this time, Dr. Fuchs had divulged to the Russians everything he knew about the

process of isolating ^{235}U for weapon use, including America's plan to build a uranium separation plant at Oak Ridge.

h. In July 1944, Dr. Fuchs met with Harry Gold for the first time in Brooklyn, New York. Dr. Fuchs was then working at Columbia University developing the gaseous diffusion system of separating fissionable uranium atoms from nonfissionable uranium atoms, and, as one of three visiting scientists, had complete access to all phases of the important work at the university. Harry Gold was presently working as a chemist at the Pennsylvania Sugar Company in Philadelphia. At this time, Dr. Fuchs passed on to Gold, who later passed it on to his Russian courier, all that was known about the extraction process to perhaps enable the Russians to construct an Oak Ridge of its own. This same year the Soviet purchasing commission was able to buy openly 1,300 pounds of uranium oxide and uranium nitrate in this country. The following year, before the first bomb was tested, we gave Russia 25 pounds of low grade uranium metal and a quantity of heavy water. Also that year, the Germans constructed their first experimental "pile" for industrial use.

i. In 1945, during the first week of the year, Dr. Fuchs spent a short holiday with his sister in Cambridge, Massachusetts, and was visited there by Harry Gold. With the six months that Dr. Fuchs worked at Los Alamos, he was now bursting with information, such as the name of the laboratory, the progress that had been made on the plutonium bomb, the principle of the implosion system and the implosion lens concept. Harry Gold arranged to meet Dr. Fuchs six months later in Santa Fe, New Mexico. In January, Sergeant Greenglass, while on furlough from Albuquerque, went to New York to visit his sister, Mrs. Anna Rosenberg, and while there wrote down everything he remembered about the explosive lens system for the implosion type weapon. In June, Dr. Fuchs drove his battered secondhand Buick over the Castillo Street Bridge on the outskirts of Santa Fe where he picked up Harry Gold for their prearranged meeting. From Santa Fe, Harry Gold traveled via a bus to 209 North High Street in Albuquerque, New Mexico, where he met with Sergeant Greenglass who turned over to Gold additional drawings and specifications of the fantastically complicated trigger or initiator of the atomic bomb. It was the perfect complement to Dr. Fuchs' material on the best method of separation of ^{235}U from ^{238}U. For his trouble, Sergeant Greenglass received $500 from Gold, and, being the patriotic American that he was, promptly bought a $50 war bond. Upon returning to the east coast in June, Harry Gold met with his Soviet contact Anatolei A. Yakovlev, the Soviet Vice Consul in New York, and turned over to him the two packets of information that he received from Dr. Fuchs and Sergeant Greenglass which included the implosive lens system, the initiator design, and the target date for the first full- scale test that would probably take place in July.

j. Louis Slotin had been chosen to test the criticality of the world's first atomic bomb; he was tickling the tail of the Trinity dragon with two silvery gray hemispheres of plutonium metal brought together by a screwdriver. At the beginning of July, there was not enough plutonium at Los Alamos to build the Trinity bomb. On the night of 15 July, David Hornig, the explosive expert who was responsible for the firing circuits of the implosion weapon, spent the night babysitting the bomb atop the 100-foot tower reading the book book entitled "Desert Island Decameron" and counting the flash-to-bang time of

the lightning bolts during a thunderstorm in an attempt to determine how close they had struck to the tower—considering all the while the possibility of their energizing the firing circuits. The first nuclear detonation occurred at 05:29:45, 16 July 1945. The temperature at its center was about 4 times that of the center of the sun and more than 10,000 times that of the sun's surface. The pressure caving down on the ground beneath the tower was over 100,000 atmospheres—the most ever to occur at the earth's surface. The radioactivity emitted was equal to one million times that of the world's total radium supply.

k. The reaction of the observing personnel is noteworthy. General Farrell turned despairingly to a fellow officer and said, "The long hairs have let it get away from them." Kistiakowsky cried deliriously, "I won the bet, I won the bet, Oppie you owe me $10." Dr. Oppenheimer, trembling, reached for his wallet, "It's empty, you have to wait," he said in utter seriousness; the two men embraced. Dr. Oppenheimer slowly dropped scraps of paper from his pocket and watched them as they were swept by the shock wave to determine the yield of the weapon which he calculated to be 20 KT. When Dr. Bush remarked that the light seemed to be brighter than any star, General Groves lapsed into one of his rare humorous moments and said, "Brighter than two stars," pointing to his major general's shoulder insignia. Later, Dr. Connant and Dr. Bush stood at attention while Dr. Oppenheimer, still shaking, allowed Dr. Rabbi to drive him into the hills to unwind; they stood at attention, their hats off, in salute to the men who built the atomic bomb. At that instant, all the plutonium produced to date was used. On 23 July 1945, the scientists at Los Alamos completed production of sufficient amounts of plutonium for the implosion combat weapon.

1–2. FIRST USE OF NUCLEAR WEAPONS

a. On 26 July 1945, the ship, Indianapolis, reached Tinian and Major Firmin and Captain Norlan delivered their shipment of ^{235}U to the waiting airmen of the 509th Composite Air Group for use in the gun assembly weapon to be used on Hiroshima. That evening the United States, Britain, and China issued to the Japanese the ultimatum that was to become known as the Potsdam Declaration. The document called for Japan to surrender unconditionally or suffer annihilation and it was signed by Truman, Churchill, and Chiang Kaishek. Russia, not yet at war with the Japanese, did not participate. Two days later, the Japanese premier rejected the ultimatum as out of hand and unworthy of public notice.

b. Though General Marshall and general Eisenhower were deeply disturbed with the idea of a surprise nuclear attack on Japan and the fact that the United States would be the first nation to use such a weapon, the decision was made by President Harry Truman. The victim cities nominated for the atomic attack were Hiroshima, Kokura, Niigata and Kyoto. All were approved by Secretary of War Stimson, except Kyoto, the ancient capital and cultural mecca of Japan. In Kyoto's place, Nagasaki was picked.

c. On 6 August 1945 at 0815 hours, the gun assembly type nuclear weapon (which had never actually been tested) was dropped on Hiroshima and detonated at 1,850 feet. The weapon was called "the little boy" or "the thin

man." This first atomic bomb, which was detonated on an enemy, had blown three-fifths of the city off the earth; 20 percent of the population was wiped out, 60 percent of the city was destroyed, 76,000 persons were injured, 13,000 were missing, and 68,000 men, women, and children died in the attack. Captain William Parsons, who had armed the bomb en route to Hiroshima aboard the Enola Gay, forwarded his report to Washington, making a note mindful of his supply responsibility that "I certify that the above material was expended to the city of Hiroshima, Japan, at 0915, 6 August 1945." The Enola Gay returned to Tinian and landed without any gas. The Indianapolis was sunk by the Japanese four days after leaving Tinian. On 9 August 1945, at 1201 hours, a duplicate of the Trinity bomb rolled out of the belly of the silver fortress, called a "boxcar," from 29,000 feet on Nagasaki and devastated the city within a fraction of a second. This weapon was the implosion type and was called the "fat man" in honor of Winston Churchill. It had cost $25 million to produce and it killed nearly 40,000 Japanese. On 12 August 1945, a second plutonium "fat man" was ready for shipment to Tinian; however, at the last minute, General Groves fortuitously delayed the shipment for on 14 August 1945 the Japanese surrendered unconditionally.

1-3. NUCLEAR WEAPONS AFTER JAPANESE SURRENDER

a. On 21 August 1945, a fatality due to radiation occurred at Los Alamos when the dragon lashed back at young Harry Daghlian and sprayed him with a lethal dose of radiation.

b. On 5 September 1945, Lieutenant Igor Couzenko, a cipher clerk in the Russian embassy in Ottowa, defected to the West taking with him many secret papers, some of which would later implicate Dr. Allen Nunn May, who gave information and small amounts of ^{239}U and ^{235}U to Karl Zabotin, who was the military attache of the Russian embassy. On 19 September 1945, Harry Gold and Dr. Fuchs had their last meeting at the door of a church on the outskirts of Santa Fe; there Dr. Fuchs described the violence of the test of the first A bomb at Trinity which he had witnessed with some of the most respected scientists in the world, including Fermi, Lawrence, Orr, Wagner, Kistiakowski, Oppenheimer, and others. In November 1945, intelligence agents during the advance of allied armies in Europe had recovered enemy documents indicating that Germany had been virtually out of the atomic bomb race from the start. Their progress was now where the United States had been in 1942. In December 1945, Karl Zabotin (code name "Grant"), who was the military attache of the Russian embassy in Ottowa, escaped to Russia from a New York port following the defection of the cipher clerk, Igor Couzenko. In February 1946, Dr. May was found guilty and sentenced to ten years in prison at Wakefield in Brookshire, England. In a painstaking examination of Dr. May's voluminous notebooks which he had filled during his years of work in the A-bomb project, the lone word "Fuchs" was discovered. Also, during the same month, David Greenglass was honorably discharged from the Army. During his bomb work with the newly developed Sandia Weapon Laboratory in Albuquerque, he had risen to head foreman of the explosive shop and had been promoted to sergeant. The Army had given him a good conduct medal as a parting gesture.

c. In May 1946, Louis Slotin became the second atomic scientist to die of a radiation accident when his screwdriver slipped on the plutonium

hemispheres and they started to lock together in a chain reaction. Slotin tore them apart with his bare hands and saved the lives of seven other scientists in the room. He himself absorbed 880 rad of radiation. It was one of the last jobs of Klaus Fuchs to report the physics aspects of what had happened in the fatal moment of the young scientist, who had determined the nuclear size of the first atomic bomb.

d. The Atomic Development Authority of the United Nations proposed that once the disarmament plan was in effect, further manufacture of atomic bombs would halt and existing stockpiles would be dismantled. That a cruel joke was perpetrated on America by these atomic spies was evident a month later when the Soviet representative to the UN denounced the proposal. The Soviets had no need of it for in the reports of Dr. Fuchs and Sergeant Greenglass; they had enough information to start an atomic arsenal of their own.

e. In November 1947, Dr. Fuchs returned briefly to the United States to take part in the Atomic Energy Commissions's so-called declassification conference. The British, on the suggestion of Scotland Yard, left him off the recommended list, but three renowned American scientists insisted that Fuchs be among the British physicists to attend. In September 1949, President Truman announced that the Russians had successfully tested their first A-bomb. Some authorities, such as General Groves, did not believe the Russians could effect this feat until the 1960's.

f. In January 1950, Scotland Yard put the question as to his wartime spying directly to Fuchs, directed in part from the lone word of his name in Dr. May's notebook. At the time of his discovery, he was working in the Harwell Laboratory, where he had recently been promoted. Paradoxically, Dr. Fuchs would not divulge the information, which he had passed on to the Russians, to the Scotland Yard personnel because, in his estimation, it was highly restricted scientific data, and they were not cleared for such material. He did give a detailed report later to Dr. Michael Terrin. In March, Dr. Fuchs was sentenced to 15 years in prison.

g. Harry Gold was now working on a heart research program at the Philadelphia General Hospital. A search was made at his home in Philadelphia on the morning of 22 May 1950, where in his bedroom they found a folded map of Santa Fe with an X mark at the Castillo Street Bridge where Harry Gold had met Dr. Fuchs in June 1945. This was the undoing of Gold for he had sworn to the agents that he had never been west of the Mississippi. Also that month, in spite of his brother-in-law, Julius Rosenberg, giving him $5,000 to escape to Czechoslovakia, David Greenglass stayed in his New York flat and was caught, turned state's evidence, and received a 15-year prison term. His wife, Ruth, was not tried.

h. After their trial, which brought forth a verdict of death in the electric chair at Sing Sing, the Rosenbergs appealed their case, but lost their appeals and were required to pay the penalty prescribed by the court. Both were executed in Sing Sing Prison, New York, on 19 June 1950.

i. In 1958, Harry Truman said in retrospect that the conservative estimate for invasion of Japan was the lives of 750,000 Americans, 250,000 killed and 500,000 maimed for life. He said "I did what I thought was right."

j. In 1959, Klaus Fuchs was released from prison in England. Within days he boarded a Polish airliner and flew to East Germany, where he announced that he was a Marxist and intended to become an East German citizen. He later became the deputy director of the East German Central Institute for Nuclear Studies. Congress' Joint Committee on Atomic Energy stated that Dr. Fuchs alone influenced the safety of more people and accomplished greater damage to a nation's security than any other spy, not only in the history of the United States, but in the history of the nations. Dr. Fuchs helped build the Trinity, Hiroshima, and Nagasaki bombs and was familiar with advanced research and development in the field of atomic weapons, which were not to reach the testing stage until 1951, and the early studies of the hydrogen bomb.

1–4. PRINCIPLES OF OPERATION OF A NUCLEAR DETONATION

a. **General.** Nuclear engagement can run the gamut from employment of small, low yield, tactical weapons to strategic weapons of megaton yields. Regardless of the manner in which these weapons are utilized, survival and resumption of mission are possible for those who understand the hazards involved. In order to understand the principles which make nuclear weapons function, a general knowledge of the language of physics is necessary.

b. **Basic Terms.** First, what is an element? An element is any substance that cannot be separated into a simpler substance by ordinary chemical means. An atom is the smallest unit of an element which retains the physical and chemical characteristics of that element. Having these two terms in hand, the definition of the atomic mass unit (AMU) follows: abbreviated "AMU" the unit atomic mass is invaluable in nuclear physics as a unit of measure, due to the fact that the masses or "weights" with which one must deal in describing atoms are so small that other units of weight become unwieldy. The AMU is based on the common isotope of carbon ^{12}C. Using this isotope as a standard mass, one AMU is further defined as one–twelfth the mass of the standard ^{12}C atom. This gives a unit of measure which can describe atoms and subatomic particles.

c. **The A–Z Number System.** ^{235}U is an example of the A–Z number system. Its construction can best be shown by the formula $^{A}_{Z}X$. In this formula, Z represents the number of protons found in the nucleus of the atom in question, or its atomic number. The X represents the chemical symbol of the element to which this atom belongs. The A represents the atomic mass number, that is, the total number of protons and neutrons, found in the nucleus. All uranium atoms have an atomic number, or Z number of 92. In fact, it is the number of protons in the nucleus that determines the element to which an atom belongs. Consequently, in ^{238}U, the A number is 238 or atomic mass number. It simply means that in this nucleus there are 238 nucleons or 238 protons and neutrons. It is easy to see now, that by using this form of "shorthand," the composition of the atom can be identified.

$^{238}_{92}U$ is an atom of uranium with 92 protons and 146 neutrons composing its nucleus. The number of neutrons is found by subtracting Z (protons) from A (total nucleons).

d. **Isotopes.** Isotopes have been mentioned earlier, but what is an isotope? The term isotope means an atom of a specific element (same Z number) that has a higher or lower mass than other atoms of the same element (different A number). Take hydrogen for example; common hydrogen, or protium, has a nucleus consisting of one proton. As defined, any atom with one proton, or Z number 1, is hydrogen. There occur in nature, two isotopes of hydrogen other than protium. First is deuterium which has a Z number of 1, but an A number of 2. The other isotope is tritium, with one proton and two neutrons in its nucleus. These three different atoms are all hydrogen, but deuterium and tritium are so-called "heavy hydrogen."

e. **Protons, Neutrons and Electrons.** The proton, found in the nucleus and represented by the symbol $^{1}_{1}p$ has a mass of approximately 1 AMU. It carries a positive charge of magnitude arbitrarily given the value of +1. The neutron, also found in the nucleus and represented by the symbol $^{1}_{0}n$, also has a mass of approximately 1 AMU. As its name indicates, it is electrically neutral. The electron is found orbiting the nucleus, much as the planets orbit the sun. It is symbolized e-. The electron mass is about 1/1840 AMU, and yet it carries a negative electrical charge of the same magnitude as the proton or -1. These are the three basic building blocks from which all atoms are made.

f. **Nuclear Energy Release.** Shortly after the turn of the century, Dr. Albert Einstein postulated that $E = mc^2$. That is, that E (energy) is equal to m (mass) multiplied by c (the velocity of light) squared. Simply stated, Dr. Einstein said that mass could be converted to energy and energy to mass in accordance with his formula. The necessity for this formula is pointed up by a simple mathematical exercise in which the experimentally known masses for protons and neutrons are used to construct the experimental atomic mass of an atom. For example, the helium nucleus is composed of two protons and two neutrons. By multiplying the values for the masses of two protons and two neutrons, then adding, there results a hypothetical value of 4.03316 AMU for the helium nucleus. The experimentally obtained mass of the helium nucleus is only 4.00277 AMU. This discrepancy can only be explained by the use of the Einsteinian concept. What has happened is this: mass has been lost, or more accurately turned into energy. The energy is required to hold the nuclear components together. In this nucleus two positive charges are held in very close proximity, and the energy required to overcome the forces of repulsion is considerable. So, mass has been converted to the required energy, and consequently lost. This phenomenon is called "mass defect." In applying Einstein's formula to the conversion of 1 gram of mass, multiply 1 gram by $(3 \times 10^{10}$ cm/sec$)^2$ which is 9×10^{20} gram cm^2/sec^2, or 9×10^{20} ergs. The definition or "ergs" is relatively unimportant if it is realized that a 9 with 20 zeros following it is an extremely large number. In fact, this energy release is approximately equal to the energy released by a 20 kiloton weapon, or the yield of the weapons detonated over Hiroshima and Nagasaki. The energy associated with a nuclear detonation comes from the product of the conversion of the many minute masses to energy in accordance with $E = mc^2$.

g. **Four Basic Types of Nuclear Reactions.** The four basic types of nuclear reactions are scatter, capture, fission, and fusion. The scatter reaction is basically similar to the carom of billiard balls. In the example of neutron bombardment of hydrogen, a neutron acts like a cue ball against the target nucleus, a hydrogen atom. The neutron strikes the proton forming the hydrogen nucleus, and physically slams it away from its original position. This reaction is academically interesting, but not of any value for weaponry purposes. Another interesting reaction is capture of the incident particle. One example is neutron capture by cadmium 113. Upon capturing the neutron, the atomic mass of the atom is raised to 114, and a gamma ray is emitted. Interesting? Yes, but of no value in constructing weapons, but two of the four common reactions <u>are</u> valuable in weaponry. Fission was the basis for the first nuclear weapons, and it is still used extensively. In this reaction a neutron is utilized against a target nucleus of the heaviest elements. A neutron at the proper energy level will cause a fissioning or splitting of the heavy nucleus into two fission fragments of much lighter A number. Associated with this splitting are two extremely important by-products. The reaction releases a relatively great amount of energy and at the same time, free neutrons are released. These facts make possible the construction of a nuclear weapon. Energy is released from the reaction, and it produces the means of sustaining itself at the same time. The fusion reaction is also important because just what it says—a fusing or joining of nuclei. The lightest nuclei, those of hydrogen, are best suited for this purpose because the energy release from this reaction is greater than the energy put into it to cause it. Consequently, the fusion reaction is desirable for weapons systems.

h. **Materials Used to Obtain Nuclear Reactions.**

(1) There are two suitable and available fissionable materials—^{235}U and ^{239}Pu. ^{235}U is a naturally occurring isotope of uranium, but it occurs as only one part in 140 of the native ore. Due to this fact, a means of extracting ^{235}U and purifying it is necessary. ^{235}U, although extremely expensive, is readily available. Plutonium is a manmade element. It does not occur in nature. Plutonium is produced by bombarding ^{238}U, which comprises more than 99 percent of the native ore, with neutrons. When the neutrons are captured, a series of transmutations takes place and the result is ^{239}Pu, an excellent fissionable material. Both of these materials are radioactive. That is, they emit particles and rays as they tend toward a stable state. This process is called "radioactive decay." The time frame for radioactive decay is called the "half-life." Half-life refers to the length of time required for a given amount of a radioactive substance to lose one-half of its radioactivity. For instance, ^{238}U has a half-life of 4.5 billion years, that of ^{235}U is 700 million years, ^{239}Pu is 24,000 years, and so on. Each radioactive isotope has its own characteristic half-life. Once a weapon with either uranium or plutonium is made, there is no need to worry about the fissionable material decaying to stability in a short time.

(2) There are two fusible materials suitable for nuclear weapons—deuterium and tritium. Both of these hydrogen isotopes occur in nature. Deuterium comprises only about 0.02 percent of natural hydrogen. Tritium occurs only as an extremely rare trace; consequently, it must be artificially

produced to make it available for use in thermonuclear weapons. Only tritium is radioactive. Deuterium is a stable isotope.

1–5. FISSION REACTIONS IN A NUCLEAR DETONATION

a. Recall that fission is the splitting of a heavy nucleus to form two lighter nuclei, which release energy and two or three free neutrons. The weapon is basically constructed with three major components—first, a source of neutrons to begin the reaction; a supercritical mass of fissionable material to sustain a multiplying chain reaction; and finally, a casing in which to put this material so that it will hold together long enough to get a sufficient number of fission generations for a profitable energy release.

b. The neutron source shoots a neutron, at the proper energy level, into the fissionable material; in this case ^{235}U. The uranium nucleus fissions, throwing off two fission fragments, releasing about 200 Mev of energy and freeing, on the average, 2.5 neutrons. These neutrons, if properly handled, will each cause the same reaction that produced them, and the number of fissions soon builds to astronomical proportions. The fission generations build in geometric progression—one causes two, two cause four, four cause eight, and so on. Each individual fission releases energy and neutrons, with fission fragments as by-products. It is interesting to note that of some 200 different isotopes that may be produced as fission fragments, all are radioactive.

c. Fissionable material is spoken of frequently in terms of what it will do. Generally speaking, a critical mass is the amount of material that will sustain a chain reaction with a steady output of energy. This is the principle used in nuclear reactors to produce a level energy release. A critical mass will not cause an explosion, nor will the chain reaction die out. A subcritical mass is an amount of material that will not sustain a chain reaction. Conversely, a supercritical mass is the amount of material necessary for a multiplying chain reaction, or explosion.

d. There are a few more "wrinkles" associated with nuclear weapons that are of general interest. Recall that a 20-kiloton yield is the result of the conversion of about 1 gram of mass to energy. The amount of fissionable material required for a weapon is considerably more than 1 gram since systems are not 100 percent efficient. However, there are five methods available to increase the efficiency of fission systems.

(1) First, purify the material to be used so as to obtain the most favorable ratio of fissionable nuclei possible.

(2) Using this purified material, a subcritical mass can become supercritical, that is, physically pushing the nuclei closer together through compression. This can be accomplished through the use of a specially designed explosive charge. Forcing the nuclei closer together greatly increases the probability of hitting fissionable nuclei.

(3) To further increase the efficiency of this system, surround the fissionable material with some substance that will reflect neutrons, which would otherwise escape, back into the fissioning material.

(4) By using a shape that will present the least amount of surface area per unit volume (a sphere), the number of neutrons escaping from the fissioning material can be reduced to a minimum.

(5) Finally, by surrounding the fissionable material with a material that will slow or moderate the "speed" at which the neutrons are moving, will greatly increase the probability of fissioning. This is due to the fact that ^{235}U and ^{239}Pu are fissioned by thermal neutrons, that is, neutrons that are "moving very slowly." By employing one, or any combination of these methods, the criticality of the fissionable material can be appreciably increased.

e. Numerous questions have arisen as to how fast the fissioning of a weapon occurs. This probably is due to the fact that the representations of fission reactions that are used somehow impress one with the feeling that the reactions take place at a rather leisurely pace. This is not the case. The average time required for a fission to occur is one shake. A shake is 1/100 of a microsecond, or 1/100,000,000 of a second. It takes about 51 fission generations to produce a 1 KT yield. It takes only 7 additional generations to raise the yield to 100 KT. It is obvious, then, that to obtain a large yield, less than a millionth of a second passes from the time the reaction starts, until all of the energy is released.

f. It is hard to imagine the meaning of "1 KT." An analogy that might help is that of TNT stacked on a football field. If the playing field in any football stadium is stacked with "bricks" of TNT on it, the stacks would have to be 9 feet high, and covering the entire field, to equal 1 kiloton, or 1,000 tons of TNT. A megaton of TNT would be a stack 9,000 feet high. Twenty megatons of TNT would make a stack covering the entire playing field, over 34 miles high! The explosive force of these weapons is truly unbelievable. The 20 KT weapon, now called a "nominal" weapon and often forgotten or sneered at because of its puny yield, was sufficient to create an absolute hell out of two fairly large cities during World War II.

1-6. FUSION REACTIONS IN A NUCLEAR DETONATION

a. The reaction utilized in "thermonuclear" weapons is fusion rather than fission. Three components are needed for the weapon; a fission trigger, fusible material, and a case to put these in. Fusion is the joining of two light nuclei to form one heavier nucleus. This reaction will take place only in an environment of extreme heat and pressure. The only practical way to obtain this environment is through the use of fission. Today, the fission weapons used on Hiroshima and Nagasaki are suitable for triggers to start off the fusion reaction. First, the fission device is detonated, creating the essential environment. Next, the fusion process begins to take place. There are a number of fusion reactions which can occur. In a typical example, two nuclei of deuterium fuse, releasing energy and a free proton, and forming a

tritium nucleus. This nucleus, in turn, reacts with a deuterium nucleus to release energy, release a free neutron, and form a helium nucleus. The resultant energy releases of two reactions described above are 4.04 Mev and 17.6 Mev, respectively.

b. One other question has come up frequently. One fission releases about 200 Mev of energy. A tritium fusion (the most efficient with regard to energy release) releases only 17.6 Mev of energy. Why is it, then, that the "hydrogen bomb" is so much more powerful than a straight fission weapon? The answer is Avogadro's Number. This number represents the number of atoms in 1 gram/atomic weight of a substance. Avogadro said that in 1 gram atomic weight there would be 6 X 10^{23} atoms. The atomic weight of ^{235}U is 235.1 AMU. Therefore, there are 6 X 10^{23} atoms in 235.1 grams of ^{235}U. The atomic weight of tritium is 3.02 AMU. Therefore, in 3.02 grams of tritium there are 6 X 10^{23} atoms. Then, if there are 235.1 grams of tritium, instead of uranium, there will be about 78 times as many nuclei available for reaction. Since the nuclei react in pairs, there could be about 39 times as many reactions. This results in an energy release about 3.5 times greater with a given amount of tritium than the energy obtained from an equal mass of uranium. This is the reason for increased yield.

1–7. SUMMATION

Discussed above have been the basic components of atoms—the proton, neutron, and electron. The fission and fusion processes were discussed and contrasted as being highly energetic processes in one of which nuclei of a heavy element are split into two lighter nuclei while the other is a joining of two light nuclei to form a heavier one. Also discussed were the time rates of the processes, their comparative energy emission and the kiloton/megaton concepts of energy yield. Lack of the basic knowledge makes understanding of nuclear warfare impossible and understanding means survival!

Section II. NUCLEAR BLAST

1–8. NUCLEAR WEAPON CASUALTIES

a. **Mass Casualties.** The effects of a nuclear detonation generate damage to an extent unknown in the annals of military weaponry. Since it is the business of the AMEDD personnel to care for the injured, and considering the high casualty potential of nuclear weapons, it would appear that members of the Army Medical Department would be remiss in their responsibility if they did not, first of all, recognize the possibility of nuclear war—to assume otherwise is totally unrealistic and an invitation to disaster; second to understand the effects of these weapons; and third, to know what can be done to minimize casualties and maximize survival. From the medical point of view, if there were a nuclear war, the medical community would face an almost impossible task, even if by some miracle all facilities, equipment and per-

sonnel survived. One needs only to view the medical resources in Hiroshima before and after the nuclear attack (shown below) to conclude that injuries from a nuclear explosion must be avoided, prevented, or at least minimized.

	Before	After
Physicians	298	28
Nurses	1,780	126

b. **Energy Release—Nuclear Versus Conventional.** An explosion, in general, results from the very rapid release of a large amount of energy within a limited space. This is true for a conventional "high explosive" such as TNT, as well as for a nuclear explosion, although the energy is produced in quite different ways. There are several basic differences between nuclear and high-explosive weapons. In the first place, nuclear explosions can be many thousands or millions of times more powerful than the largest conventional detonations. Second, a fairly large proportion of the energy in a nuclear explosion is emitted in the form of light and heat, generally referred to as "thermal radiation." Third, the nuclear explosion is accompanied by highly penetrating and harmful rays, called the "initial nuclear radiation." Finally, the substances remaining after a nuclear explosion are radioactive, emitting similar radiations over an extended period of time. This is known as the "residual nuclear radiation."

1-9. NUCLEAR WEAPONS DETONATIONS

a. **Nuclear Energy Distribution.**

(1) The release of energy in an explosion of a nuclear weapon is rated in terms of the quantity of conventional high explosives (TNT) which would release the same energy. The early weapons released energy equivalent to several thousand tons of TNT. A thousand tons of TNT is called a kiloton (KT) of TNT. Thus, weapons are rated as having the equivalent of so many KT of TNT; the energy released is called the yield of the weapon. For example, each of the two weapons dropped on Japan had a yield of about 20 KT. The development of hydrogen bombs has meant that weapons may have energy release in the order of millions of tons of TNT. The yields of such weapons are stated in megatons (MT) of TNT equivalent. One megaton is equal to 1,000 kilotons. To understand what kind of weapons these are, it may be well to look at a few comparative figures:

(a) Energy equivalent of one Hiroshima or Nagasaki type bomb—20,000 tons of TNT.

(b) Energy released by conventional bombs dropped on Berlin during all of World War II—35,000 tons of TNT.

(c) Energy equivalent of a 1-MT bomb—1 million tons of TNT.

(2) The energy released by conventional bombs dropped by the Allies upon Japan and Germany and the occupied countries of Europe during World War II was 5 million tons of TNT (approximately).

(3) It is possible to construct one bomb whose yield would be greater than all of the high explosives ever detonated for any reason since the beginning of human history. The limit on weapon yield is no longer one of construction—it is, rather, one of practical usability. For strategic targets, large yields are desirable. For tactical application, on the battle field of the future, weapons ranging in yield from 1 KT or less up to several times the yields of those dropped upon Japan will be desirable. It is doubtful that any field commander will need or want the largest yields.

(4) The transfer of energy from the nuclear weapon to the surrounding media begins immediately and is exhibited in three distinct casualty producing effects (fig. 1–1). Although the distribution of energy varies somewhat depending on the weapon and condition of the explosion, it is generally about as follows:

(a) Fifty percent as blast and shock: As the altitude increases, the percentage of the total energy appearing as blast is reduced due to the low air density.

(b) Thirty-five percent as thermal radiation: As the altitude is increased, the percentage of the total energy appearing as thermal radiation is increased, since less thermal radiation is absorbed by the intervening air. It has been estimated that at great heights, where the density of the air is extremely low, more than 50 percent of the fission energy might appear as thermal radiation at some distance from the exploding weapon.

(c) Fifteen percent as nuclear radiation (initial, 5 percent; residual, 10 percent).

(5) Initial radiation is defined as those forms of radiations emitted from the fireball and nuclear cloud within the first minute after detonation. Those radiations emitted after the first minute are referred to as residual radiation and are usually associated with neutron induced activity and fallout. The 1-minute cutoff time is an arbitrary figure based on the fact that the fireball and nuclear cloud rise so fast that after 1 minute the radiations emitted cannot reach the ground in amounts that are considered militarily significant.

b. **Types of Burst.** Nuclear weapons may be burst at any point from deep below the surface to very high in the air. Tactically, nuclear bursts are classified according to the manner in which they are employed.

(1) Subsurface burst. A subsurface burst is an explosion with its center beneath the surface of land or water. This type of burst is used to cause damage to underground targets and structures and to cause cratering.

(2) Impact or contact surface burst. An impact or contact surface burst is an explosion at the surface of land or water, or at a height above the surface less than the maximum fireball radius. This type of burst will cause fallout and cratering, and may damage hard underground targets located relatively near the surface of the earth.

(3) Airbursts. An airburst is an explosion in the air, above land or water, at a height greater than the maximum radius of the fireball.

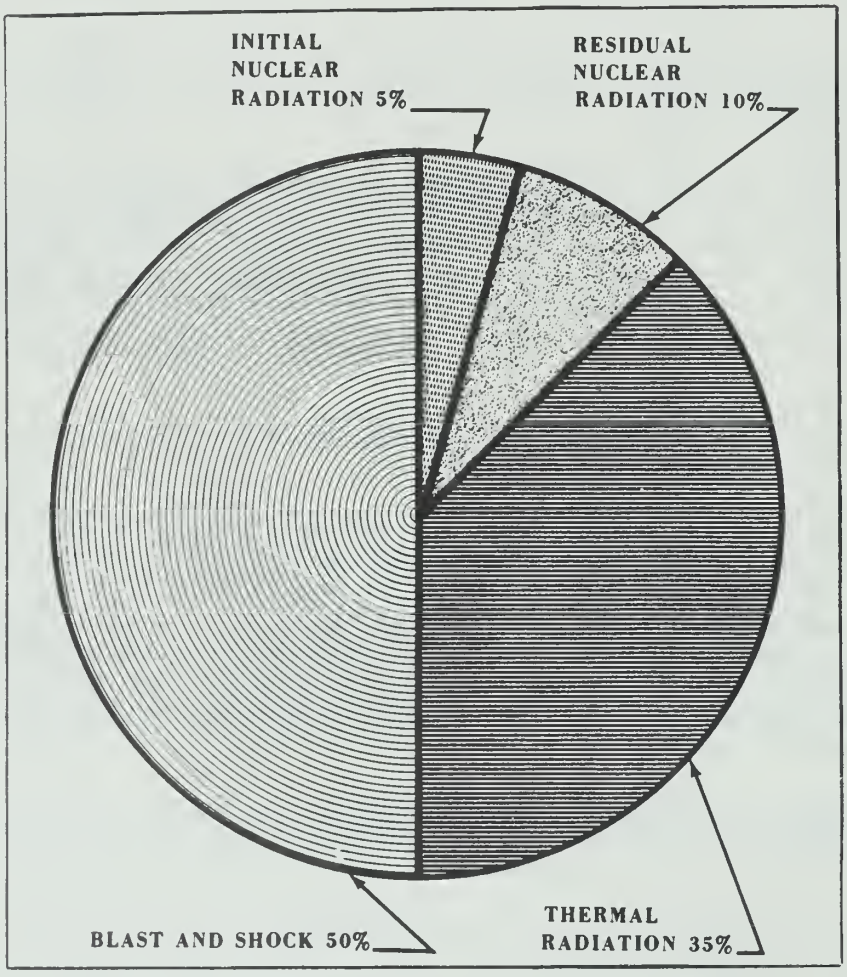


Figure 1-1. Distribution of energy.

1-10. BLAST PHENOMENA

a. In discussing the effects of a nuclear detonation, the terms "ground zero" and "radius of damage" are often used. Ground zero is the point on the ground directly under, at, or above the burst. Horizontal distances along the ground to which various effects extend are measured from ground zero. Every nuclear burst produces a radius of damage for each associated target element and degree of damage. For example, a weapon will have one radius of damage for moderate damage to wheeled vehicles, another radius of damage for severe damage to wheeled vehicles, and another for casualties to protected personnel. It is clear that in the employment of nuclear weapons, levels of damage must be understood and the three standard levels of damage must be defined in as precise a manner as possible.

(1) The first level is light damage. Light damage is that degree of damage which does not preclude the immediate use of the item in its primary mission. A good example of this would be a vehicle. Suppose that the windshield, tarp, and hood of a truck were blown off by the blast effect. While the truck has sustained damage, it can be driven without requiring any repairs. This, then, is light damage.

(2) The second level is called moderate damage. This is defined as that degree of damage requiring extensive repairs before it can be used for the purpose for which it was intended.

(3) The highest level is severe damage. This is defined as that damage which makes replacement more feasible than repair.

(4) Personnel casualties, unlike material damage, are not classified as to degree. Whenever personnel cannot perform their duties and require medical attention, they are considered to be noneffective, or casualties.

b. When a nuclear weapon is detonated in the air, there is formed an intensely hot, luminous sphere of gases, called the fireball. Initially, the fireball expands so rapidly that a layer of highly compressed air is formed on the surface of the fireball. The atmosphere cannot get out of the way and piles up on the surface forming a shock front or blast wave. As the fireball cools and its rate of expansion slows down, the blast wave breaks away from the fireball and moves out in all directions at a very high rate of speed. As it loses energy, it loses speed until it reaches the speed of sound (1000 ft/sec) and continues thereafter to move at that rate. As long as there is nothing in its way, it will travel out in all directions; however, when that portion of the blast wave traveling downward from an airburst strikes the surface of the earth, it will be reflected or "bounced back." There will not only be the primary or incident blast wave, but there will also be a reflected blast wave. Since the reflected wave is traveling through heated air, it travels faster than the primary blast wave and somewhere on the ground, depending on the height of burst and energy of the explosion, it overtakes the primary blast wave and reinforces it to produce a much stronger pressure front. This merging of the reflected and primary blast wave is called the "Mach effect." The fused blast waves, which have a much greater damaging

effect than either the primary or reflected wave, are referred to as the "Mach stem." It is to be noted that there is essentially only one blast wave from a surface or subsurface burst; hence, the Mach effect is a distinguishing feature of the airburst.

c. As the blast wave moves outward, it exerts two types of damaging pressures on all material in its path. While their separate intensities and effects can be measured, it is important to keep in mind that they always occur together.

(1) The first pressure is static overpressure. (The maximum value at the blast wave front is called the peak overpressure). As the name implies, it has nothing to do with motion. This is a squeezing or crushing force which surrounds the object and continues to apply pressure from all sides until the pressure returns to normal. Targets, such as buildings, which are sensitive to and are damaged primarily by static overpressure, are called diffraction targets. The strength of the blast wave is measured in pounds per square inch (psi) above atmospheric pressure; i.e., 14.7 psi at standard sea level conditions.

(2) The second pressure is called dynamic pressure, and as the name implies, there is motion. As the blast wave moves away from the burst point, it is accompanied by high winds. Dynamic pressure is a measure of the forces associated with these winds. This pressure causes damage by pushing, tumbling, or tearing apart a target element. Targets, such as trucks, tanks, and most military equipment, which are damaged primarily by dynamic pressure, are called drag-type targets. While the two types of pressures are considered separately, they always occur together. Some indication of the relationship between static overpressure and maximum wind velocities for sea level conditions is shown below:

5 psi—160 mi/hr

10 psi—290 mi/hr

30 psi—670 mi/hr

(3) As a frame of reference as well as an important aspect of protection from airblast, the relationship between peak overpressure (psi), expected physical damage, and approximate range for a 20-KT and 20-MT air-burst weapon is below:

Material	psi	Damage	Approximate Range in Miles 20 KT	20 MT
Glass windows	.5–1	Shattering	3.6	36
Wood frame buildings residential type	2–3	Moderate	1.9	19
	3–4	Severe	1.5	15
Brick apartment house	3–4	Moderate	1.5	15
	5–6	Severe	1.1	11
Multistory, steel frame, office building	6–7	Moderate	1	10
	8–11	Severe	.75	7.5
Motor vehicles	9–13	Moderate	.7	7
	13–20	Severe	.5	5

Table 1–1. Comparison of effects of psi.

(4) It is of interest to examine what happens when a blast wave moves past a structure, since the general interactions of a human body with a blast wave are similar. Suppose that on the roof of the building there was a pressure gauge which was instantly responsive to any change in pressure and a 20–KT weapon was detonated in the air about 2 miles away. For a short interval after the detonation, there would be no change on the pressure gauge, since it takes the blast wave about 8 seconds to travel the distance from the point of detonation to the building (about 2 miles). When the blast wave arrives, the pressure on the gauge will suddenly increase sharply. At this time the blast wave will bend around the structure, engulf the building, and tend to crush it. Simultaneously, a great rush of air or strong winds will strike the building and tend to push it, tear it apart, and hurl debris through the air. The blast wave acts on the building during its passage of the positive or compression phase for about 1.2 seconds. It is during this interval that most of the destructive action of the blast wave will be exper–enced. As the blast wave passes the building, the pressure begins to fall off, returns to normal, and then sinks below that of the surrounding atmos–phere. For most of the period when the pressure is below atmospheric pres–sure, the transient winds reverse direction and blow back towards the point of detonation. This is described as the negative or suction phase of the blast wave. There may be some destruction during the negative or suction phase, but less than in the positive phase. As the negative phase passes, the pressure returns to that of the normal atmosphere. The blast wind has then effectively ceased and the destructive action of the airblast is over.

(5) Another important feature of the blast wave is its duration. When the blast wave with a high peak overpressure hits an object, it surrounds the object and continues to apply pressure from all sides in decreasing strength until the pressure in that vicinity returns to normal atmospheric pressure. This is how static peak overpressures produce damage. The longer an object is subjected to the squeeze of static peak overpressure, the more the damage which can normally be expected.

(6) As the positive phase travels away from the burst, the peak overpressure decreases, but at the same time, the length of the positive phase increases both in time and in actual distance. For example, when the blast wave is .3 mile from a typical 1–KT airburst, the peak static overpressure is 7.5 psi and the duration of the positive phase is .28 seconds; while at .6 mile, the peak static overpressure is only 2.4 psi, but the duration of the positive phase is .38 second.

(7) The duration of the blast wave is important because for some types of targets, such as tanks or trucks, a long, steady push of lesser strength will do as much or more damage than an instantaneous shock of greater strength.

1–11. MODIFYING INFLUENCES ON AIRBLAST PHENOMENA

a. **Weather.** Rain and fog cause attenuation of the blast wave because energy is dissipated in evaporating the moisture in the atmosphere.

b. **Surface Conditions.** The reflecting quality of the surface over which a weapon is burst can significantly influence the distances to which blast effects extend. Generally, reflecting surfaces such as ice, snow, and water increase the distance to which static overpressure extends. Generally, they decrease the distance to which dynamic pressures extend.

c. **Topography.** Most data concerning blast effects are based on flat or gently rolling terrain. There is no field method of calculating changes in blast pressures due to hilly or mountainous terrain. In general, static overpressures are greater on the forward slopes of steep hills and diminish on reverse slopes when compared with pressures at the same distance on flat terrain. Blast shielding is not dependent upon line of sight considerations because blast waves easily bend around apparent obstacles. The influence of small hills or folds in the ground is considered to be negligible. Hills may decrease dynamic pressures and offer some local protection from flying debris.

d. **Cities or Built–Up Areas.** These areas are not expected to have a significant effect on the blast wave. Structures may provide some local shielding from flying debris. Some local pressure increases may result from structures channeling the blast wave. However, the general airblast characteristics in cities and urban areas are considered to be essentially the same as those for open terrain.

e. **Forests.** Forests will not have a significant effect on blast wave characteristics, which are essentially the same as for open terrain.

f. **Height of Burst.** The height of burst determines the extent to which the blast wave is reflected and influences the strength of incident and reflected blast waves.

1–12. DIRECT BLAST INJURY

a. **General.** The phenomenon of blast interacts biologically with people to cause injuries. It should be pointed out, first, that among the injured that survived the explosions over Hiroshima and Nagasaki (over 70,000 in Hiroshima and 21,000 in Nagasaki), approximately 70 percent experienced some type of blast injury—fractures, lacerations, contusions, or abrasions. For ease of understanding, the effects of airblast on personnel are referred to as either direct or indirect. Direct blast injuries are caused by the variations in environmental pressure accompanying a blast wave—that is, the fast–rising overpressures of long duration. Due to the body being rapidly engulfed by the blast wave and subjected to compression, decompression, and transmission of pressure waves through the organism, damage occurs mainly at junctions between tissues and air–containing organs and at areas of union between tissues of different density, such as cartilage and bone joint soft tissue. The chief consequences are ruptured eardrums, hemorrhage, and occasional rupture of abdominal and thoracic organs. The lungs are particularly prone to hemorrhage and edema (liquid extrusion) and if the injury is severe, air reaches the veins of the lungs, and hence the heart and arterial circulation. Death may occur in a few minutes from air embolic obstruction of the vessels of the heart or brain, but may also ensue from suffocation caused by hemorrhage or edema in the lung tissues.

b. **Probability of Fatalities.**

(1) Based on laboratory and field studies with animals, the esti–mated peak overpressures required for men to produce various probabilities of fatality are given below:

Probability of Fatality (percent)	Peak Overpressure (psi)
1	30–50
50	50–75
99	75–115

(2) Damage to the lung can occur at overpressures as low as 15 pounds per square inch, which may develop from reflection of an incident peak overpressure of 6 or 7 pounds per square inch.

(3) Rupture of the normal eardrum is apparently a function of the age of the individual as well as of the rate of rise and fall, duration, and height of the peak overpressure. Failures have been recorded at overpressures as low as 5 psi, ranging up to 40 or 45 psi. The best value of the overpressure for 50 percent probability of eardrum rupture appears to be between 20 and 30 psi. Ruptured eardrums alone usually will not produce

ineffectiveness, although some people suffer pain, dizziness, and some degree of hearing loss. Sinus hemorrhage and bleeding from the nose is common in animals exposed to blast, but no reliable quantitative information is available. Fracture of the thin orbital bones into the adjacent sinus cavities has been observed, but the appropriate values for man are not known.

(4) The geometry* in which a person is exposed to the blast wave may have a large effect on his response. When the pressure wave reaches an individual in the open or in a long hallway or tunnel, much of it may be as a result of reflection. The reflected pressure, and hence the effective pressure, may then be more than double the incident or open terrain pressure. Depending upon the dimensions of entryway openings and internal volume, the overpressure inside a structure may be much less, equal to, or greater than the incident pressure. There may also be alterations in the rate of pressure rise and the duration of the positive phase. Under certain circumstances, an individual inside a structure would not only be exposed to the initial overpressure, but, in addition, to reflections of the blast wave from the walls. A location against a wall facing the blast wave is the most hazardous position as regards direct blast effects, because the overpressure from the initial reflection is then maximal.

(NOTE: The word "geometry" is used here to be a composite term to describe the location of an individual in relation to the details of his environment that may affect the blast wave characteristics.)

(5) The predicted maximal ranges inside which direct blast injuries may be expected for various yield airbursts are shown below:

Injury	Range in Miles		
	20 KT	100 KT	20 MT
Eardrum failure threshold (No pressure reflection) 5 psi	1.2	2	12
Lung damage threshold (No pressure reflection) 15 psi	.58	1	5.8
Lethality near 50 percent (No pressure reflection) 50 psi	.27	.48	2.8

(6) From the nuclear bombings of Japan, the direct blast effect was not specifically recognized as a cause of fatality, though it no doubt contributed significantly to early mortality even though most of the lethally injured individuals may also have received mortal injury from debris, displacement, fire, and thermal and nuclear radiation. Further, the high mortality among those with significant direct blast injuries can be explained by the overwhelming disruptive effects of the Japanese bombings on medical and

rescue services. For these reasons, primary blast effects, except for eardrum rupture, were not commonly seen among Japanese survivors.

(7) Although direct blast injuries are extremely hazardous and represent a type of injury to be avoided, it is doubtful that they will present a serious problem to the medical service in any nuclear conflict. If one is in the area where overpressures are sufficient to produce severe direct blast injuries, he may be simultaneously lethally burned and irradiated. For a 1-MT air-burst, for example, 50 psi (near 50 percent lethality) is experienced about one mile from ground zero. At this location the thermal energy would be measured in hundreds of calories (about 800 cal/cm^2) and the nuclear radiation in the thousands of rads (about 15,000 rad). At the distance where lung damage may occur (15 psi range), about 200 cal/cm^2 and 20 rad are experienced. A possible exception to this is the case of people in an inadequately designed shelter which provided good shielding from thermal and nuclear radiation, but which permitted entry of the blast wave or actually caused reinforcement or amplification of the airblast that entered. The important point is that not many direct blast injuries will be seen from the detonation of a nuclear weapon.

1-13. INDIRECT BLAST INJURY

Indirect blast injuries consist of fractures, concussions, lacerations, abrasions, and puncture wounds of body organs and cavities—resulting from the collapse of buildings, missiles flying through the air, and the physical displacement of man by the blast winds.

a. Flying Missiles.

(1) The physical and biological factors that determine the seriousness of injury from penetrating or nonpenetrating objects striking an individual are many, and as a consequence, the hazard to man is not quite so clear as is the case with damage from direct overpressure. In fixing the hazard to man from flying or falling objects, one must consider missile velocity, mass, size, and shape, along with the specific areas of the body involved. Ignoring most of these and for the sake of brevity, the missile problem will be limited and simplified here by using only impact velocity and missile mass to illustrate the conditions for skin lacerations, penetration into the abdominal cavity, fracture of feet and legs, and closed fracture of the skull.

(2) Velocity criteria for the production of skin lacerations by penetrating missiles, such as glass fragments, are not known with certainty. It has been estimated, however, the threshold for skin lacerations from a 10-gram glass fragment appears to be about 50 feet per second in 10 feet of travel. The constraint of 10 feet of travel was arbitrarily placed upon a distance of travel because this was thought to be applicable to the average house. Concerning the probability of penetration of the abdominal cavity by glass, some reliable information is available based on the results of field work and laboratory studies. The impact velocities arbitrarily fixed in 10 feet of travel for glass fragments of different masses, corresponding to 1, 50, and 99 percent probability, are shown below. These figures represent

impact velocities with unclothed biological targets. Protective effects of clothing for low velocity debris are not well understood.

PROBABILITIES OF GLASS FRAGMENTS PENETRATING ABDOMINAL CAVITY			
	Probability of Penetration (percent)		
Mass of glass Fragments (grams)	1	50	99
	Impact Velocity (ft/sec)		
0.1	235	410	730
0.5	160	275	485
1.0	140	245	430
10.0	115	180	355

(NOTE: It should be noted that any wound involving a cavity is almost always accompanied by serious infections, even if a nearby organ escapes critical injury. The threshold for such injury can be taken to be about 100 feet per second for a 10-gram glass missile. For smaller fragments, the threshold velocity is higher. It is unfortunate that similar kinds of data for sharp, frangible objects are not available for the eye.)

(3) The predicted maximal ranges with overpressures and wind velocities inside which a 10-gram glass fragment will attain sufficient impact velocity for a 5-0 percent probability (180 ft/sec) of penetration of the abdominal cavity for various yield airbursts are shown below:

YIELD	RANGE (miles)	OVERPRESSURE (psi)	WIND VELOCITY (MPH)
20 KT	1.3	4.4	140
100 KT	2.2	4.3	138
20 MT	15.0	3.6	115

(4) With regard to nonpenetrating missiles, the head appears to be the critical organ, with the possible exception of impact over the spleen and liver. Little is known, however, concerning the physical requirements for injury from impact with the body wall near the spleen and liver; severe hemorrhage and death from rupture of these organs is not uncommon after accidents. With regard to head injury, a hard missile with a mass of 10 pounds striking the head at a velocity of 10 ft/sec (7 MPH) appears to be a "safe" impact velocity; 15 ft/sec (11 MPH) appears to be the threshold for both cerebral concussion and skull fracture. At velocities of 23 ft/sec or above (16 MPH), skull fracture can be expected nearly 100 percent of the time.

b. **Falling Objects.** It is interesting to note that a 10-pound object dropped from a height of 6 feet attains an impact velocity of about 19 ft/sec, with a probability of skull fracture about 50 percent. It is apparent that an object this size does not have to travel very far or very fast to cause serious injury to man.

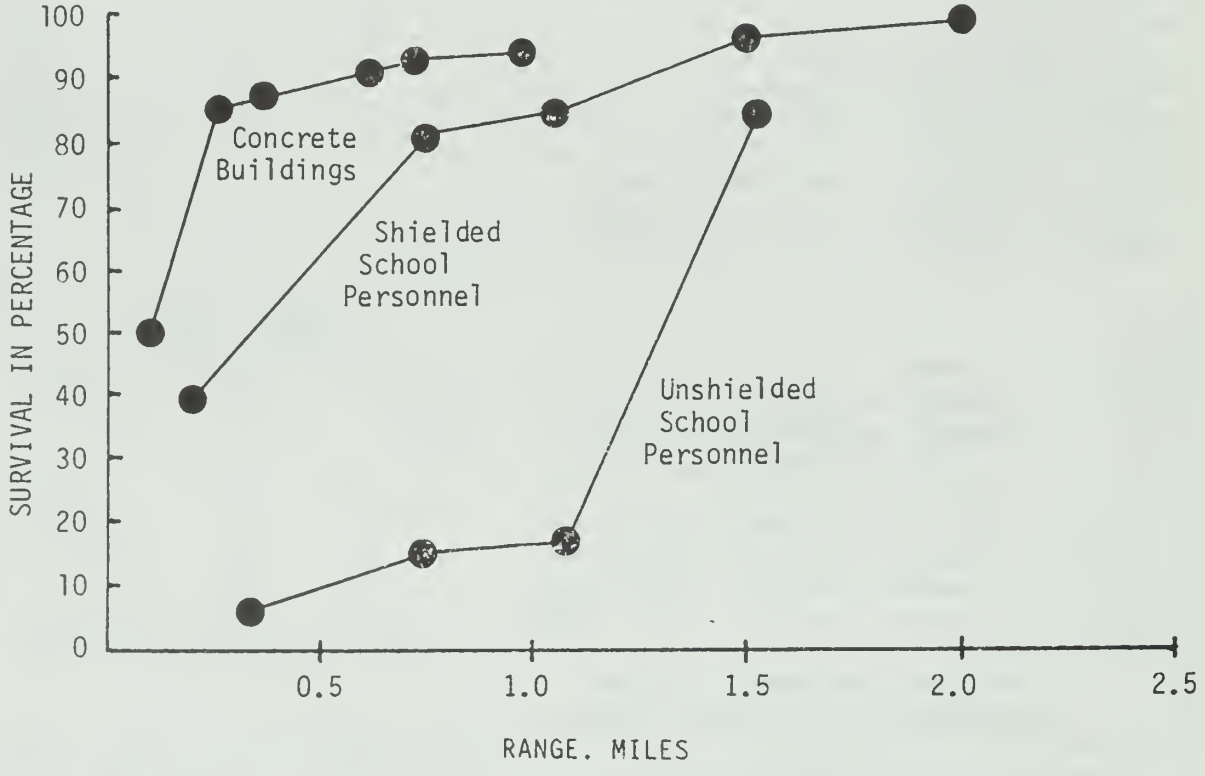
c. **Translational Injuries.** With respect to the problem of physical displacement of man from blast-produced winds, it is likely that most injuries will occur during decelerative impact with some hard object. Since a hard surface will cause more serious injury than a soft one, the damage criteria given below, based on various data, including auto accidents, refer to impact of the displaced body with a hard, flat surface. Translation velocities were computed at displacement distances of 10 feet. Fractures of the heel,feet,and lower extremities can be expected at impact velocities of 11 to 16 ft/sec for hard surfaces with knees locked. The predicted maximal ranges inside which indirect blast injuries may be expected for various yield airbursts are shown to give a general feel for the problem and clearly indicate that blast hazards must be regarded as a major cause of injury and death.

Mostly "safe".....10 ft/sec
Skull fracture threshold.....13 ft/sec
Skull fracture near 50 percent.....18 ft/sec
Lethality threshold (whole body).....20 ft/sec
Skull fracture near 100 percent.....23 ft/sec
Lethality near 50 percent (whole body).....26 ft/sec
Lethality near 100 percent (whole body).....30 ft/sec

INJURY	RANGE IN MILES 20 KT	100 KT	20 MT
Penetrating Missiles—10 Gram Glass Fragment			
1. Skin laceration threshold (50 ft/sec)	3	5	34
2. Serious-wound threshold (100 ft/sec)	1.9	3.4	22
3. Serious wounds near 50 % (180 ft/sec)	1.3	2.2	15
4. Serious wounds near 100 % (300 ft/sec)	.9	1.6	11
Physical Displacement of Man with Impact with Hard Surface			
1. Mostly "safe" (10 ft/sec)	1.5	2.8	23
2. Skull fracture threshold (13 ft/sec)	1.3	2.4	20
3. Fracture feet and legs (14 ft/sec)	1.2	2.3	19
4. Skull fracture near 50 % (18 ft/sec)	1.1	2.1	18
5. Lethality threshold (whole body) (20 ft/sec)	1	1.9	17
6. Skull fracture near 100 % (23 ft/sec)	.95	1.1	15
7. Lethality near 50 % (whole body) (26 ft/sec)	.9	1.7	14
8. Lethality near 100 % (whole body) (30 ft/sec)	.82	1.5	13

1–14. PROTECTIVE MEASURES

a. The phenomenon and the destructive effects of blast have been described along with the best available assessment of these effects on man. Since blast may be a major cause of injury or death and recognizing the almost impossible task facing the medical service, it is hard to escape one significant conclusion; namely, that injuries from blast may be at least minimized. This is not as difficult as most believe it to be. To illustrate this point, the survival data from Hiroshima below shows the percent survival as a function of range from ground zero under different conditions of exposure. Three groups of individuals are shown: (1) On the far right, school personnel in working parties, who were mostly in the open at the time of the detonation. (2) The curve in the central area applies to school personnel mostly inside schools when the explosion occurred. (3) On the far left is the survival curve for over 3,000 individuals located inside concrete buildings at burst time. Survival here applies to individuals known to be alive 20 days postshot.



b. There are a number of simple lessons portrayed by these survival curves which actually relate human experience with a nuclear detonation.

(1) First, the 50 percent survival ranges for the three curves from the right to left of 1.3, 0.45, and 0.12 miles forcefully emphasized the importance of the conditions of exposure.

(2) The area of complete destruction at Hiroshima has been described as covering a circle of about 1.2 miles radius (4 square miles), a range at which 4–5 psi existed. At this range there was an overall survival of near 90 percent. It is apparent, therefore, that one must not confuse the area of complete destruction of houses (a physical concept) with "complete destruction" of people. Even in to near 0.2 miles, there was 5 percent overall survival.

(3) The great, good fortune of just being indoors and shielded against the most far-reaching effect, direct thermal radiation, is illustrated by the 50 percent survival range of 0.45 mile for school personnel, mostly inside, compared with 1.3 miles for those mostly outside. This proved so even though the fact of being inside involved exposure to falling and flying debris and higher pressure reflections. Apparently the latter hazards are relatively less than the dangers from direct thermal radiation.

(4) The marked value of simply being inside concrete buildings is illustrated by the 50 percent survival range of 0.12 mile. This is most significant. There were 400 individuals inside the forward building, the post office. Two hundred became casualties almost immediately, no doubt mostly because of blast effects. The remaining 200 were alive 20 days later. Though many, no doubt, subsequently succumbed because of exposure to ionizing radiation, the effective shielding against thermal radiation, blast pressures, winds, and debris is quite clear. There was nothing special about the building except it was built to seismic codes.

(5) The illustrated progressive decrease of the range for 50 percent survival from 1.3 miles to 0.12 miles—about a factor of 10—as it varied with conditions of exposure occurred by accident in Hiroshima. These facts bring out clearly the greatly improved chances of survival from a nuclear explosion that could result from the planned adoption of suitable warning and protective measures.

c. The problem of providing complete protection from blast is virtually impossible; however, there is much that can be done to reduce materially the number of casualties. On the battlefield, trenches, foxholes, and bunkers offer considerable protection. It takes about 15 psi to collapse these field fortifications.

d. In cities, where a blast-resistant shelter is not available, protection should be sought in the strongest building that is accessible. Protection against flying debris can be obtained by taking refuge in a location, preferably selected in advance, that is least likely to be entered by blast debris. In addition, individuals should stay away from windows and easily breakable materials, such as plaster walls or ceilings. In the collapse of buildings as a result of blast, heavy members and pieces of structural materials and contents will fall or be hurled about. There is a dual hazard of being hit and trapped; therefore, positions next to walls in basements offer the best protection. Above ground, however, the safest locations are generally near, but not against, walls and away from doors and windows. Even if there is no prior warning of a nuclear attack and the first indication is the flash of light, there may still be the opportunity to take some protec-

tive action against the effects of blast. Some approximate values of the times which elapse between the instant of the explosion and the arrival time of the blast wave front at various distances from ground zero for airbursts of various energy yields are given below. In distances at which the peak overpressure is 1 psi or less, the times are not included.

DISTANCE (Miles)	10 KT	100 KT	10 MT
	(Time in Seconds)		
1	3.7	3.3	1.5
2	8.1	7.4	5
5	–	21	16
10	–	–	37
20	–	–	83

e. It is seen that at 10 miles from a 10–megaton airburst, which is within the area where protection against blast could be effective, about 40 seconds would elapse before arrival of the blast wave. If prompt action is taken, a person in a building could reach a position of the type indicated earlier. In the open, some protection against the blast may be obtained by falling prone, and remaining in that position until the wave has passed. In the prone position, with the head directly toward or directly away from the explosion, the area of the body exposed to the onrushing blast wave is relatively small and the danger of displacement is thereby decreased.

1–15. SUMMATION

The blast and shock effect accounts for approximately 50 percent of the energy released by a nuclear detonation, except under certain conditions. The blast wave moves outward from the fireball at approximately the speed of sound and can be reinforced by the reflected wave, depending upon the height of burst. This wave interaction is known as the Mach effect, or Mach stem, and causes the overpressures in the region through which it passes to be greatly increased. Diffraction–type targets are those sensitive to static overpressure or crushing; drag–type targets are those sensitive to dynamic pressure or tearing, tumbling, and displacement. Damage is classified by degrees as severe, moderate, or light. Blast injuries are of two main types; namely, direct injuries associated with exposure of the body to the environmental pressure variations accompanying a blast wave, and indirect injuries resulting from impact of missiles on the body or as the consequences of dis–placement of the body as a whole.

Section III. THERMAL AND INITIAL RADIATION

1-16. THERMAL RADIATION

a. **Fireball Development.**

(1) Almost immediately after a nuclear explosion, the weapon residues incorporate material from the surrounding medium and form an intensely hot and luminous mass, roughly spherical in shape, called the "fireball." Generally there is about 35 percent of the energy from the nuclear weapon appearing as thermal energy or thermal radiation. This thermal radiation will travel large distances through the air and will be of sufficient intensity to cause moderately severe burns of exposed skin as far away as 12 miles from a 1-megaton explosion, on a fairly clear day. The warmth may be felt at a distance of 75 miles. Because of the enormous amount of energy liberated per unit mass in a nuclear weapon, very high temperatures are attained. These are estimated to be several tens of million degrees, compared with a few thousand degrees in the case of a conventional explosion. As a consequence of these high temperatures, a considerable amount of energy is released in the form of electromagnetic radiations of short wave length. Initially, these are mainly in the soft x-ray region of the spectrum, but the x-rays are absorbed in the air, thereby, heating it to high temperatures. This heated air, which constitutes the fireball, in turn radiates in a spectral region roughly similar to that of sunlight received at the earth's surface. It is the radiation (ultraviolet, visible, and infrared) from the fireball, traveling with the speed of light, which is received at distances from the explosion.

(2) For an airburst at altitudes below 50,000 feet, the thermal radiation is emitted in two pulses. In the first pulse, which lasts about a tenth part of a second for a 1-megaton explosion, the surface temperatures are mostly very high. As a result, much of the radiation emitted by the fireball during this pulse is in the ultraviolet region. Although ultraviolet radiation can cause skin burns, in most circumstances following an ordinary airburst the first pulse of thermal radiation is not a significant hazard in this respect. In contrast to the first pulse, the second radiation pulse may last for several seconds, e.g., about 10 seconds for a 1-megaton explosion; it carries about 99 percent of the total thermal radiation energy. Since the temperatures are lower than in the first pulse, most of the rays reaching the earth consist of visible and infrared (invisible) light. It is this radiation which is the main cause of skin burns of various degrees suffered by exposed individuals up to 12 miles or more, and of eye effects at even greater distances, from the explosion of a 1-megaton weapon. The radiation from the second pulse can also cause fires to start under suitable conditions.

b. **Thermal Radiation Effects.** The main direct effects of thermal radiation on human beings are skin burns, generally called flash burns to distinguish them from flame burns, and permanent or temporary eye damage. Burns are classified by "degree"; first-degree burns being mild in nature, roughly similar to moderate sunburn; they should heal without special treat-

ment. Second-degree burns are associated with blister formation, and if a significant area of the body is involved, medical attention is necessary; third-degree burns which involve the entire thickness of the skin, can occur at shorter ranges. Indirect (or secondary) burns also occur and are referred to as "flame burns"; they are identical with skin burns that would accompany (or are caused by) any large fire no matter what its origin. In addition, individuals in buildings or tunnels close to ground zero may be burned from hot gases and dust. The effects of thermal radiation on the eyes fall into two main categories: (1) permanent (chorioretinal burns) and (2) temporary (flash blindness). Concentration of sufficient direct thermal energy, due to the focusing action of the eye lens, can cause the permanent damage. The focusing occurs, however, only if the fireball is in the individual's field of view. When this happens, chorioretinal burns may be experienced at distances from the explosion which exceed those where the thermal radiation produces skin burns. As a result of accidental exposures at nuclear weapons tests, a few burns of this type have been received at distances up to ten miles from explosions of approximately 20-kilotons energy yield. Temporary "flash blindness" or "dazzle" can occur in persons who are too far from the explosion to suffer chorioretinal injury or who do not view the fireball directly. Flash blindness results when more thermal energy is received on the retina than is necessary for image perception, but less than is required for burn. From a few seconds to several minutes may be required for the eye to recover functions.

c. **Protective Measures.** If an individual is caught in the open or is near a window in a building at the time of a nuclear explosion, evasive action to minimize flash burn injury should be taken, if possible, before the maximum in the second pulse. At this time only 20 percent of the thermal energy will have been received, so that a large proportion can be avoided if shelter is obtained before or soon after the second thermal maximum. The major part of the thermal radiation travels in a straight line and so any opaque object interposed between the fireball and the exposed skin will give some protection. At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point. An individual caught in the open should fall prone to the ground in the same way, while making an effort to shade exposed parts of the body. Getting behind a tree, building, fence, ditch, bank, or any structure which prevents a direct line of sight between the person and the fireball will give a major degree of protection. Clothing of the proper kind provides good protection against flash burns. Materials of light color are usually preferable to dark materials because the former reflect the radiation. Clothing of dark shades absorbs the thermal radiation and may become hot enough to ignite, so that severe flame burns may result. Woolen materials give better protection than those of cotton of the same color, and the heavier the fabric the greater the protection. An air space between two layers of clothing is very effective in reducing the danger of flash burns. Protection against eye injury is difficult, especially for those persons who happen to be facing the burst point.

d. **Factors Affecting Thermal Radiation.** Several factors will affect thermal radiation.

(1) Weapon size. The thermal output or pulse of weapons increases markedly with increasing yield of weapon.

(2) Altitude of the weapon. The altitude at which a weapon is detonated will determine what fraction of its output is thermal. In a very high altitude burst there is much less atmosphere to be heated into a fireball and the nature of the electromagnetic output is considerably changed. In a subsurface burst, the thermal output is absorbed within a short distance below the surface and is not hazardous to personnel.

(3) Atmospheric conditions. The degree of visibility markedly alters the ranges at which thermal effects can occur. Cloud cover, fog, and rain all have definite and varying effects.

1–17. INITIAL NUCLEAR RADIATION

a. The nuclear explosion is accompanied by highly penetrating and harmful invisible rays, called initial nuclear radiation. One of the special features of a nuclear explosion is the fact that it is accompanied by the emission of nuclear radiation: gamma rays, neutrons, beta particles, and a small proportion of alpha particles. Most of the neutrons and a part of the gamma rays are emitted in the actual fission process, i.e., simultaneously with the explosion. The initial nuclear radiation refers to the radiation emitted within one minute of the detonation. Since the ranges of the alpha and beta particles are comparatively short, initial nuclear radiation may be regarded as consisting only of gamma rays and neutrons produced during a period of one minute after the nuclear explosion. Gamma rays and neutrons can produce harmful effects in living organisms. It is the highly injurious nature of these nuclear radiations, combined with their long range, that makes them such a significant aspect of nuclear explosions. Most of the gamma rays accompanying the actual fission process are absorbed by the weapon materials and are thereby converted into other forms of energy. Thus, only a small proportion of this gamma radiation succeeds in penetrating any great distance from the exploding weapon, but there are several other sources of gamma radiation that contribute to the initial nuclear radiation. Neutrons produced in fission are to a great extent slowed down and captured by the weapon residues or by the air through which they travel. Nevertheless, a sufficient number of fast (fission) neutrons escape from the explosion region to represent a significant hazard at considerable distances away. Shielding from initial nuclear radiations (gamma rays and neutrons) is not a simple matter. For example, at a distance of one mile from a 1–megaton explosion, the initial nuclear radiation would probably prove fatal to a large proportion of exposed human beings even if they were surrounded by 24 inches of concrete. Even though gamma rays and neutrons differ in many respects, their ultimate effects on living organisms are much the same.

b. The fact that initial nuclear radiation can reach a target from directions other than that of the burst point has an important bearing on the problem of shielding. Adequate protection from gamma rays can be secured only if the shelter is one which surrounds the individual so that he can be shielded from all directions. Various types of building materials offer varying amounts of protection from initial nuclear radiation, but the more

massive the construction, the better the protection. On the outside, a simple one-man foxhole can provide some protection.

Section IV. RESIDUAL IONIZING RADIATION

1-18. INTRODUCTION

A tremendous pulse of radiation is released from the fireball of a nuclear weapon at the time of detonation and shortly thereafter. This is the initial radiation which has been previously discussed. It does not end the radiation problem. In fact, in a very real sense, the problem of dealing with radiation from the nuclear burst may be just beginning. Initial radiation is, by definition, over in a minute, and there is not much that can be done about it which was not done prior to the burst. However, there are other sources of radiation which will continue to present a problem for some time after the bomb is detonated. This radiation which continues after that first minute of initial radiation is called residual radiation. Residual radiation poses a much greater problem to the military officer than does the initial radiation, because he must deal with it over some period of time. The effect of this residual radiation on troops and the success of military missions will be determined by the judgment exercised in making decisions relative to this residual radiation.

1-19. TYPES OF RESIDUAL RADIATION

a. **General.**

(1) There are two general types of residual radiation which may be of military significance; these are induced radioactivity and radiological fallout. Residual radiation delivers its dose of radiation to personnel over quite a long period of time (hours, days, or weeks), while initial radiation doses are delivered almost instantly. Residual radiation also differs from initial radiation in that it contains no neutrons, whereas neutron radiation is a very important component of initial radiation. Both types of radiation include gamma, beta, and alpha radiation. Beta radiation is of limited importance in residual radiation, but is of no concern in initial radiation because the short range of beta particles restricts it to the fireball. In fallout environments, individuals can come into direct contact with materials emitting the beta radiation. Under these conditions, beta radiation may be significant.

(2) Since initial radiation emanates from the fireball, essentially it reaches the individual from a point source in space. Residual radiation, on the other hand, reaches the individual from what is called an extended source. Generally, it comes from a two-dimensional source—a circle around the individual on the ground. This is true for both the induced radiation area and fallout. In addition, fallout, while in the process of descending, emits radiation from a three-dimensional source, since some of the radioactive material is in the air as well as on the ground.

(3) Generally speaking, residual radiation is less energetic than initial radiation. Therefore, it is less penetrating and is easier to protect against by shielding than initial radiation.

b. **Induced Radiation.**

(1) The two principal categories of residual radiation have been mentioned: induced radiation and fallout. Induced radiation is emitted from radioactivity that is produced in the surface in the vicinity of a nuclear weapon detonation. Neutrons can be captured by certain materials in the surface, converting them to unstable atoms which will emit radiation over a period of time. Fallout, the other major source of residual radiation, results from fission products in the nuclear cloud which slowly settle back to earth as the cloud drifts downwind.

(2) When a nuclear weapon is detonated, a tremendous flux of neutrons is released. Some of these neutrons strike the earth's surface and penetrate up to 18 or 20 inches. Most substances in the soil are not affected by neutrons; however, there are certain constituents of the soil which become radioactive when they capture neutrons. Some of these elements are: sodium, aluminum, manganese, iron, and silicon. Different types of soils contain varying quantities of these materials which can be made radioactive by induction; therefore, the area where the weapon was burst will influence the amount of radioactivity produced. Even small quantities of these elements may become highly radioactive when irradiated with neutrons.

(3) Induced radioactivity is also produced by surface bursts; but under these circumstances, it is usually completely overwhelmed by the fallout problem.

(4) The induced radiation area is characterized by its localized circular pattern. Since the neutrons producing the induced radioactivity leave the fireball in all directions, they intersect the earth in a circular pattern with the greatest quantity of neutrons striking the surface directly beneath the point of burst. Thus, the pattern shows the highest levels of induced radioactivity at the center of the circle, and this gradually diminishes as one moves from the center of the circle to the periphery of the pattern. Weather conditions have no effect on this pattern, since wind, rain, temperature, and all other meteorological factors do not affect the path of the neutrons.

(5) The induced radiation area is most difficult to decontaminate. Other types of radiological contamination generally result from the depositon of radioactive dusts on the surface. The penetration of neutrons may actually create radioactivity within the surface to a depth of several inches. Decontamination of the surface within the induced pattern by removal of the surface requires the removal of the top 4 to 6 inches of soil. Even though the pattern of induced radioactivity is small when compared with a fallout pattern, the removal of the surface material to such a depth presents a formidable problem.

(6) The decay characteristics of induced radioactivity are considerably different from those of fallout. Fallout material (fission products) consists of a complex mixture of many radioactive isotopes and daughter products of decay. Induced radioactivity, on the other hand, is produced in relatively few elements within the soil. Therefore, the decay of this induced radioactivity will vary with soil composition.

(7) Because of the small size of the pattern of the induced area, it is not of great significance in military operations. Combat forces may move into areas of induced radioactivity within an hour or two of the burst while dose rates are still rather high. Through judicious use of instruments and by avoiding the center of the pattern, doses can still be kept very low. Passage through the area in vehicles, particularly armored vehicles, will reduce the time of exposure and give considerable protection through shielding. The most difficult military problem would be posed in the situation which required forces to occupy a vital piece of terrain which was involved in the induced pattern. This problem may be solved by occupying the position in a horseshoe or doughnut-shaped pattern and by digging foxholes in conjunction with scraping back the top six inches or so of earth around the foxhole. There is not much likelihood that a mission will exist in this area for medical units.

c. **Radioactive Fallout.**

(1) General. Fallout presents a much more serious military problem than does induced radiation. When a nuclear weapon is burst close to the surface of the earth so that the fireball intersects that surface, radiological fallout may be expected. When the weapon is detonated, the fission process produces many new atoms which are radioactive. They are unstable, and in reaching stability they will eventually emit one or more types of radiation. The quantity of radiation represented by these fission products is truly enormous. In the fireball, these fission products are vaporized so that when they later condense or solidify as the cloud rises, they are extremely small particles. When the weapon is detonated in the air, these fission products remain in the form of very tiny particles which drift downwind with the cloud, settling back to earth so slowly that they are eventually distributed over a vast area, sometimes over half of the earth's surface, and not until months or even years after the burst. Thus, fission products from airbursts emit much of their radiation harmlessly high in the air, and they never become sufficiently concentrated on the earth's surface to constitute an acute hazard.

(2) Local/early. On the other hand, when the weapon is burst close enough to the earth's surface for the fireball to touch that surface, quantities of debris from the surface are picked up in the fireball. These are mixed with the vaporized fission products in the fireball. When the fireball cools sufficiently, the vaporized fission products condense as in the airburst, but much of this condensation takes place on particles of debris from the earth's surface. Since these debris particles are much larger than the fission particles, they tend to settle out of the nuclear cloud as it drifts with the wind, carrying the radioactive fission products with them. Thus, radioactive materials are carried back to the earth's surface within

hours and concentrated in a pattern which, while it may be large (several thousand square miles), is sufficiently covered with radioactive materials to represent a hazard to life. This is called "local" fallout. The area covered with radioactive materials in this way is called the fallout pattern or area. "Local" fallout is defined as that which reaches the ground within the first 24 hours after the detonation and within several hundred miles of ground zero.

(3) Worldwide fallout.

(a) There is another type of fallout, the so-called "worldwide" fallout. Worldwide fallout originates in two ways: When a nuclear burst produces local fallout, it also produces finely divided fission products which, by chance, have no opportunity to condense upon surface debris. These remain very finely divided particles and fall to earth very slowly. They may be in the troposphere for several weeks, months, or years before settling back to earth. The other source of worldwide fallout is the very large megaton weapon. This weapon is so powerful that its rapidly rising nuclear cloud strikes the tropopause with such force that it is able to penetrate through into the stratosphere. The tropopause is a temperature inversion layer between the troposphere (where we live) and the stratosphere. This layer acts as a barrier to the cloud from kiloton nuclear weapons, but not to the larger megaton weapons. When radioactive materials from nuclear clouds break through into the stratosphere they do not readily repenetrate the barrier formed by the troposphere; therefore, they do not return to earth rapidly. It takes a matter of years for even half of the material to make its way down through the tropopause to eventually be carried back to earth with precipitation.

(b) The worldwide fallout is not a military problem. By the time this radioactive material reaches the earth, most of its radiation has been dissipated and it is so widely scattered as to require special, low reading laboratory instruments to even detect its presence. This is the "strontium 90" problem which is a subject for debate by philosophers and geneticists. There are other sources of fallout. No fission process is 100 percent efficient. Therefore, some unfissioned nuclear fuel will be present in the cloud and in the fallout. These nuclear fuels are alpha emitters. So, besides the beta and gamma radiation from fission products, fallout will contain alpha emitters. Also, elements of the bomb casing and in the soil or structures in the target area are all susceptible to conversion to radioactive materials through neutron induction. In some cases these induced radioactive materials may have a significant effect upon the fallout decay characteristics, causing decay to take place more or less rapidly than predicted. These induced radioactive materials are, of course, gamma and beta emitters just as are the fission products.

(c) Nevertheless, the principal source of radiation in fallout remains the fission products themselves. Induced radiation will only rarely produce significant change in decay characteristics and will simply add its gamma and beta radiation to the total fallout problem.

d. **Factors Affecting the Pattern.** Fallout patterns can vary considerably in size, shape, and in the degree of hazard presented. There are

many factors which can influence the fallout pattern. Some of these are the yield and design of the weapon, the height of burst, meteorological conditions, and the nature of the terrain.

(1) The fission yield of the weapon determines the amount of fission products produced, and, therefore, the total quantity of radioactive material available. The fission yield is a function of weapon design as well as total weapon yield. The total number of neutrons which escape from the weapon is also a function of weapon design. Since the total number of neutrons available for induction of radioactivity determines the quantity of induced radioactivity which may be present in the eventual fallout, it can be seen that the design of the weapon and its fission yield both determine the total quantity of radioactive material in the atomic cloud and the amount available for fallout. The total weapon yield also helps to determine the height to which the cloud will rise, and therefore, the size of the fallout pattern.

(2) The height at which a nuclear weapon is burst will determine the quantity of debris in the cloud upon which radioactive materials can condense. The more debris in the cloud and the larger the particles, the sooner they will return to earth and the smaller the fallout pattern. Also, the dose rates will be higher within the smaller pattern. Generally, then, when weapons are burst high in the air but still low enough for the fireball to intersect the surface), the larger the fallout pattern, the less concentration of radioactive material in the pattern.

(3) Terrain may affect the fallout pattern in two ways. First, the composition of the soil directly beneath the burst will determine the quantity and type of induced radioactive materials which find their way into the fallout; second, the nature of the terrain over which the cloud passes will have its effect on the pattern, principally through the production of local "hot spots" or "skip areas." Local wind currents are usually a function of the terrain over which they occur.

(4) Meteorological conditions obviously have a tremendous effect upon the size and shape of the fallout pattern as well as its location. Of all meteorological factors, winds have the greatest effect upon the pattern. Wind direction determines the location of the pattern, and wind velocities determine its shape. It is not just the surface wind which affects the fallout pattern, but all the winds between the top of the nuclear cloud and the ground. All of the winds which are going to affect a nuclear cloud are called the "effective" wind. This effective wind will indicate the velocity and direction in which the cloud will move and fallout will form. Naturally the larger particles in the cloud will fall faster than the smaller particles and will be affected less by winds as they fall. These larger particles fall closer to ground zero, and since they generally carry more radioactivity, form the "hottest" part of the fallout pattern. The highest dose rates are found at the centerline of the pattern. The familiar elongated downwind fallout pattern is formed from the throw out area at ground zero, gradually decreasing in dose rate until the pattern fades into background radiation levels at some distance from ground zero. The direction of the effective wind determines the direction of the long axis of the fallout pattern, and the magnitude of the

effective wind determines whether it will be long and narrow or short and broad. The faster the effective wind, the longer and narrower the resulting pattern.

(5) Other meteorological factors will affect the fallout pattern. Notable among these is rain or other precipitation. If precipitation falls through all or part of a drifting nuclear cloud, it scours some of the radioactive material from the cloud and carries it to earth in greater concentration than would otherwise develop. This is called "rain out." Smaller nuclear bursts of less than 10 KT do not push their clouds high enough to pass over the rain clouds, which generally drift at about 15,000 feet in temperate zones. In this case, even an airburst of 10 KT or below could result in significant local fallout—or rather, rain out. For surface bursts, while fallout is in progress some portion of the cloud is always below the level of rain clouds, and therefore, rain out could occur. Airbursts of large weapons are not subject to rain out because their clouds rise too high.

1–20. NUCLEAR WEAPONS INTELLIGENCE REPORT

a. **NBC Reporting System.** In view of the extent and influence of a fallout pattern, the tactical commander requires some items of intelligence following enemy use of nuclear bursts. He needs to know such items as location and type of burst, yield, and other elements which may be of intelligence value. The medical commander also requires some of these items in order to effectively perform his medical mission. Obviously, to be of value, this information must be rapidly disseminated on the battlefield. To facilitate the timely transmission of this material, a series of five NBC reports has been standardized throughout NATO.

b. **Observation.**

(1) There are several observations that can be made when the enemy employs a nuclear weapon. These include illumination time, azimuth towards the attack, location, delivery means, type of burst, flash–to–bang time, crater dimensions, cloud width and stabilized cloud top or bottom elevation. This intelligence information is necessary in order to alert other headquarters of the burst and to provide necessary information for estimation of yield and fallout prediction as required. The NBC reporting system consists of an alphabet wherein each item designates one and only one item of information. The meaning of each of the letters is found in Appendix A, GR 76–332–100, page A–6 through A-11. **Note: cGy and rad can be used interchangeably throughout this subcourse.**

(2) These letter items are used in one or more NBC reports. Formats for the five NBC reports are found in Appendix A, GR 76–332–100, pages A–6 through A-8. Artillery units have primary responsibility for reporting to the NBC element. Other units are responsible for making the basic observations for their own information and processing by unit NBC personnel. Normally, this information will not be transmitted to other headquarters or units. An NBC–2 report is compiled from two or more NBC–1 reports and represents an evalua–tion of data from the basic reports. The NBC–5 message provides a means for the NBC element to disseminate information concerning

confirmed dose rates on the ground. This may be done by means of a trace or overlay of isodose rate contour lines or by the message format of the NBC–5 report.

(3) The NBC–4 report is a report of radiation dose rates at the reporting unit or other specified location. Note that the location of the reading, the dose rate, and the time are minimum reporting facts.

(4) The NBC–3 message is a fallout prediction prepared by the NBC element at division and higher levels. It contains all the necessary information for receiving units throughout the command to plot a fallout prediction on their maps.

(5) There is one additional message that, although not a part of the standardized NBC reporting system, plays an extremely important role in fallout prediction. The Effective Downwind Message transmits wind speeds and directions for six different yield groups of nuclear weapons. This information is compiled by the NBC element and disseminated throughout its area of responsibility. The basis is wind data provided periodically by the Air Force or Artillery. The format is found in Appendix A, GR 76–332–100, page A–14.

1–21. FALLOUT PATTERN

Fallout has the potential to severely restrict operations of the nuclear battlefield. Because of this, procedures for predicting fallout and the implications of these fallout predictions on operations have been developed.

a. **General.** There are two nomograms with which one should become familiar prior to entering into a discussion of procedures for predicting fallout. The nomogram in Appendix A, GR 76–332–100, page A–37, is used to determine cloud radius directly from weapon yield. Cloud radius is determined by connecting the left and right–hand yield columns with a straight edge and noting the cloud radius under the straight edge in kilometers. The cloud radius is always rounded up to the nearest whole number. For example, a cloud radius of 2.5 km is rounded up to 3 km. The nomogram in Appendix A, GR 76–332–100, page A–36, is used to determine the downwind distance of Zone I. The estimated weapon yield is connected with a straight edge to the effective wind speed (from the Effective Downwind Message) and the Zone I downwind distance read under the straight edge in kilometers. Again, round up to the next higher whole number. The downwind distance of Zone II is twice the Zone I distance from ground zero.

b. **Overall Area.** In a nuclear warfare situation, a commander will have several questions concerning enemy nuclear surface bursts. He must know the direction fallout is moving, the speed at which it is moving, and the potential radiation hazard within his area of influence. The Army fallout prediction predicts an area wherein there is a high assurance that fallout will occur. This area is laterally defined by radial lines extending out from ground zero, and usually 40 degrees apart. The downwind boundary is defined by the Zero II arc between the lateral boundaries. This fallout predicted area is actually larger than the area in which fallout is expected to occur and the boundaries are not absolute; that is, some fallout will probably occur

outside the predicted area. However, barring major wind changes, all military significant fallout should occur somewhere within the area. In an attempt to answer the question as to the potential radiation hazard within the predicted area, it is subdivided into two areas within which exposed, unprotected personnel may receive significant total doses of radiation.

c. **Procedures for Prediction of Fallout.** To satisfy command requirements at all echelons, two procedures for predicting fallout have been adopted. The primary procedure is the detailed method employed by the NBC element at division and higher headquarters and disseminated throughout the command by means of an NBC-3 message. The supplemental procedure is a simplified method that can be used by any unit in the field. Procedures for these methods are found in Appendix A, GR 76-332-100, page A-31. Perhaps the most important step in processing a fallout prediction is to analyze the potential situation in the area of concern and adjacent areas. The calculating and plotting is worthless without this last important step; for from this will emerge decisions as to required reactions for protection of personnel. Although a fallout prediction has several inherent inaccuracies, it still is the best protection in the unit area.

1-22. PRINCIPLES OF PROTECTION

a. **General.** When it appears likely that fallout is appearing, there are two courses of action available—evacuation of unit to a new location or staying in the fallout area. Evacuation from the threatened area into an area of no fallout seems the most logical, but many other things must be considered in making this determination. What are some of the determinants? What are some of the factors that a commander must take into consideration?

b. **Important Considerations.**

(1) The most important determinant in a situation like this, as in any situation, is consideration of the mission of a unit. This mission is the only reason for the unit to be in a situation of nuclear war. The mission of treating the injured and the sick and getting them back to duty is the prime consideration.

(2) Transportation is vital if the unit is going to move from one area to another. Is there enough transportation organic to the unit to move all of its patients, all of the personnel, and all of the equipment? If there is not enough organic transportation, is it available from other units?

(3) Another determinant is "shelter." Shelter is a necessary part of operations in nuclear warfare. Shelter is needed for patients and personnel in order for them to survive. Three things are necessary for survival in nuclear warfare. One of these is RADIAC instruments to detect the presence of radiation; another is shelter, in order to continue operations; and the third is an exposure control system for personnel and patients. This will preclude one person going outside to shake off the top of the dozer trench each time, or one person continually going out to refuel the generator, or one person being continually on the trash detail to remove the rubbish that accumulates. This exposure control system also implies that a record of the

radiation exposure to those individuals that get a greater exposure than the normal person and the average dose to the rest of the personnel and patients. This is important when the commander considers radiation history.

(4) Another determinant of importance is the "enemy action." Just because the enemy has used a nuclear weapon does not mean that he is going to throw up his hands and shout: "It is all over! We have done it now! We have shot a nuclear weapon!" Remember that the idea of most wars is to acquire land and people—that the enemy is going to follow up his nuclear strike with ground forces to take and hold the ground. As a consequence of this, consideration must be given to: "Is the enemy advancing? Is he overrunning the units?"

(5) Radiation history of the unit must be considered. There should be an exposure control system along with shelters and RADIAC instruments, which are a necessary part of the operation in nuclear warfare. This exposure control system can give an idea of what sort of radiation dosage that the unit as a whole has suffered.

c. **Protection from Radioactive Fallout.** Protection may be achieved by three principles: distance, time, and shielding. If all three principles could be applied, the operation of a medical unit could be continued.

(1) Distance. The sun is very intense in the amount of heat energy that it releases, but only a small portion of that energy is received on the face of the earth. The distance between the earth and the sun is the protection factor. Distance between the source of radiation and people will give a like degree of protection. Consider a person sitting in the center of the room, as opposed to a person sitting beside the wall. The person sitting near the wall would be closer to a source of fallout on the outside and would get a greater dose of radiation than the person sitting in the center of the room. Consider the soldier who is in the middle of a uniform fallout field. Actually 50 percent of his dose is coming from within a circle of 10 meter radius around him. If he can keep the source of radiation 10 meters away from himself, the soldier will have reduced his radiation exposure by about 50 percent.

(2) Time. All radioactive materials decay with the passage of time. In fallout, there are many different fission products: some with very short half-lives in the range of milliseconds, and some with very long half-lives. Time will help reduce the dose rate as the radioactive materials decay.

(3) Shielding. The third principle of protection, shielding, is merely putting something between the person and the source of radiation. A good source of shielding from gamma radiation used in the walls of X-ray rooms is lead and it is generally backed up by very dense concrete. Materials that protect from X-rays also give protection from gamma radiation. The greater the density of the material, the better will be the protection. Shielding then from gamma is a combination of mass and thickness of the material used. On the nuclear battlefield the materials that are available will have to be used and what is lacked in density of material will have to be made up in

thickness of the material. The thickness of material which will reduce the radiation dose rate to one-half its original value is known as the half-value layer (HVL). Some typical half-value layers are: 0.7 inch steel; 2.2 inch concrete; 3.3 inch dirt; 4.8 inch water; and about 9 inch wood. Thus 4.4 inches of concrete will reduce the radiation intensity to 1/4 of the original value (1/2 times 1/2). Another term commonly used to express the efficiency of a shelter is transmission factor (TF). By definition:

$$TF = \frac{\text{inside dose (or dose rate)}}{\text{outside dose (or dose rate)}}$$

therefore, the TF will always be a fractional number less than one. The third term is protection factor (PF) and that is the inverse of transmission factor, or,

$$PF = \frac{\text{outside dose (or dose rate)}}{\text{inside dose (or dose rate)}}$$

The PF for a shelter will always be greater than one.

(4) Examples.

(a) Earth, a commodity that is normally afforded everywhere, has a rather good value as shielding, with a half-value layer of thickness of 3.3 inches. So a bunker or a building covered with a few feet of earth will provide some protection from gamma radiation.

(b) Consider the walls of a building with about 13 inches of concrete. Concrete has a half-value layer thickness of 2.2 inches; so this would mean that walls constitute about six half-value layers. What would be the dose rate on the inside if the dose rate on the outside was 100 rad/hr? There would be six half-value layers to work with. One half-value layer would reduce the inside to 50 rad/hr; two half-value layers would reduce the dose/rate to 25 rad/hr; three half-value layers would reduce it to 12 1/2 rad/hr; four layers to 6 1/4 rad/hr: five layers to 3 1/8 and the sixth half-value layer down to about 1 1/2 rad/hr.

(5) Civil defense. Civil defense has spent millions of dollars in trying to find what will be the best shelter available to people. They have considered many types of buildings and they have come to the conclusion that the subbasement of a multistory building will provide the best protection. The first floor of a one-story frame house provides a protection factor of 2. A protection factor is a measure of the amount of protection received from a certain shelter. It is a ratio of the outside dose of radiation to the inside dose; so as the protection factor gets larger, more protection is available. Lightweight materials, not much thickness, combined with distance, have small

protection factors. Normally, as the density of building materials is increased, the thickness of the walls are increased because they must bear more load—so in the subbasement of a multistory building, there is a great thickness of walls, a large distance from the outside to the center of the inside, and a lot of earth surrounding the subbasement.

(6) Field expedient shelters--foxholes.

(a) In many locations there will not be an existing building available, so one must rely on field expedient shelters, which are shelters developed as the need arises. A soldier who is standing in the middle of a fallout field is being hit by various components of gamma radiation from all sides. Perhaps his only solution is a foxhole where he gets a great deal of shelter by merely getting beneath the surface of the earth. If this particular soldier had merely squatted down, he would have achieved more protection because he would have increased the distance that the radiation has to travel before hitting him.

(b) Any device that can be used to reduce the dose of radiation that personnel may receive, may be of great importance to future health. The foxhole is an excellent fallout shelter for the individual. The Army Medical Department's mission is to provide appropriate care for their patients. Field expendient shelters assume a larger proportion than a simple individual foxhole. A dozer trench is commonly used. The dozer trench is constructed using a bulldozer to cut the desired width, length, and depth in the ground. The dozer trench, must accommodate liter patients and allow adequate room for medical personnel to move freely among the patients. This shelter has a protection factor ranging from 7—10 because of reduced amounts of radiation permitted to interact with the patients. Additional protection can be provided by using a piece of canvas material as a cover and periodically having personnel dust off the canvas or throw it back in order to remove the fallout that may have landed there. The canvas alone will not give any protection from the standpoint of keeping the fallout particles at some distance from the individuals and patients. The dozer trench is not a good shelter from the standpoint of having things such as running water, or electricity, or waste disposal, or heating system, but it still will provide protection from fallout and it can be easily constructed.

(c) Several field expedient shelters have been experimented with. The sandbag tent offers a protection factor of about 4 but it takes a very large amount of manpower and materiel to sandbag all the tents in an evacuation hospital. Perhaps this might be done to one tent, perhaps a command post, or perhaps the operating room in order that a procedure in process would not be interrupted by having to go to a shelter. The dug—in tent offers a protection factor of about 5, but it also takes a large amount of engineer support.

d. **Summary.** Protection from fallout is achieved by three principles: distance, time, and shielding; time must pass before radioactivity decays, resulting in a lesser dose of radiation; dense thick shields reduce the intensity of the radiation, thus reducing the dose received. In reacting to the threat of fallout, the commander may decide to stay in place or to

evacuate. He makes this decision based primarily on the mission, but he certainly will consider transportation, shelters, enemy action, radiation history, and perhaps many more variables, such as supply, communication between units, and others.

EXERCISES, LESSON 1

REQUIREMENT. The following exercises are to be answered by marking the lettered response that best answers the question; or by completing the incomplete statement; or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson, and check your answers with the solutions.

1. List the three distinct casualty producing effects of a nuclear weapons detonation.

_____

_____

_____

2. Initial or prompt nuclear radiation is emitted during the first _____ after a nuclear weapons detonation.

3. What percentage of total energy released at the time of a nuclear weapons detonation is the shock or blast effect?

_____

4. What percentage of total energy released at the time of a nuclear weapons is the thermal effect?

_____

5. List the three type of nuclear bursts.

_____

_____

_____

6. A psi of 5 coincides with approximately _____ mph wind velocity.

7. List three factors which affect thermal radiation.

_____

_____

_____

8. Two types of burns, caused by thermal radiation, are _____ and _____.

9. Which of the following had charge of the Manhattan Engineering project?

a. Edgar Sengier.

b. Klaus Fuchs.

c. William Parsons.

d. Leslie R. Groves.

10. List the four basic types of nuclear reactions.

_____

_____

_____

_____

11. What reaction is utilized in thermonuclear weapons?

_____

12. What are the three basic components of atoms?

_____

_____

_____

13. List four basic differences between nuclear and high-explosive weapons.

_____

_____

_____

_____

_____

14. What degree of burn is associated with blister formation?

_____

15. Which of the following NBC reports provides information concerning confirmed dose rates on the ground?

a. 1.

b. 2.

c. 3.

d. 5.

16. In seeking protection from fallout, which of the following factors must be considered by a commander?

a. Mission of the unit.

b. Transportation available.

c. Shelter available.

d. Anticipated enemy action.

e. Unit radiation history.

f. All of the above.

SOLUTIONS TO EXERCISES, LESSON 1

1. Blast and shock, thermal radiation, and nuclear radiation. (para 1–9a(4) (a)–(c))

2. 60 seconds or 1 minute. (para 1–9a(5))

3. 50% (para 1–9a(4)(a))

4. 35% (para 1–9a(4)(b))

5. Subsurface burst; surface burst; and airburst. (para 1–9b(1)–(3))

6. 160 mph (para 1–10c(2))

7. Weapon size; altitude of weapon; and atmospheric conditions. (para 1–16d (1)–(3))

8. Flash and flame burns. (para 1–16b)

9. d (para 1–1f)

10. Scatter; capture; fission; and fusion. (para 1–4g)

11. Fusion. (para 1–6a)

12. Proton; neutron; and electron. (para 1–4e)

13. Nuclear explosion can be a great many times more powerful; a fairly large proportion of energy in a nuclear explosion is emitted in the form of light and heat; nuclear explosion is accompanied by initial nuclear radiation; and substances remaining after a nuclear explosion are radioactive. (para 1–8b)

14. 2nd degree. (para 1–16b)

15. d (para 1–20b(2))

16. f (para 1–22b(1)–(5))

LESSON ASSIGNMENT SHEET

LESSON 2	--Ionizing Radiation Injury.
LESSON ASSIGNMENT	--Paragraphs 2-1—2-11.
MATERIALS REQUIRED	--None.
LESSON OBJECTIVES	--After completing this lesson, you should be able to:
	2-1. Discuss the acute radiation syndrome.
	2-2. List the symptoms of acute radiation injury.
	2-3. Describe the recommended treatment for acute radiation injury.
SUGGESTION	--After completing lesson assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 2

IONIZING RADIATION INJURY

2–1. INTRODUCTION

In addition to blast, thermal injury, and initial nuclear radiation from a nuclear weapon, which may produce a large number of casualties, residual radiation is emitted. It has a similar potential. This ionizing radiation injury may not be observed for days or even weeks.

2–2. TYPES OF RADIATION

a. An understanding of the ionizing radiation injury hazard associated with the use of nuclear and thermonuclear weapons requires a clear appreciation of the types of radiation produced by such weapons and their characteristics, especially with respect to their ability to penetrate deeply into the body. It must be understood at the outset that many variables, including the type and energy of the radiation, the time during which it is received, the presence or absence of associated injuries, the extent of the body exposed, individual biological susceptibility, and, of greatest importance, the total dose received influence the response in the irradiated victim. These variables are mentioned not to add confusion to a confusing problem, but rather to acknowledge their importance in arriving at a departure point for describing the syndrome of acute radiation injury. Any description which presumes to paint a clinical picture of radiation injury must be based fairly firmly on the optimistic assumption that the dose received and absorbed is known. The difficulty in establishing this absorbed dose for an individual or group, especially in a situation of mass casualty production in warfare, is no minor one.

b. Although an increasing variety of ionizing particles and rays exists, or can be produced in the laboratory, only alpha and beta particles, neutrons, and gamma rays are associated with the detonation of nuclear weapons. Of these, only neutrons and particularly gamma rays concern us in exploring the problem of large numbers of acute whole body ionizing radiation injuries. Both of these are present at the time of detonation while only gamma is present in the fallout. The assumption is made, too, that for whole body effects, neutrons are of the same biologic effectiveness as gamma rays in producing injury. (It is true, of course, that for specific organs or for particular effects, this assumption is not valid). Proceeding from this assumption, the abbreviation rad will be used to describe the unit of dose and may be considered to represent the roentgen, roentgen equivalent, the rad (radiation absorbed dose), or the rem (roentgen equivalent man).

2–3. SOURCES OF HUMAN DATA

In the development of a typical clinical picture of the acute radiation syndrome, it is necessary to extract segments of information from a variety of sources to produce a complete and representative sequence of events. No one source alone is complete enough from the standpoint of dose information, dose range, medical documentation of early findings, numbers involved, and types of radiation to provide the data required.

a. The Japanese bomb casualties, as they have come to be known, represent by a wide margin the largest number of human beings ever exposed to large doses of penetrating ionizing radiation. Documentation, particularly soon after the injury, was not good and dose determination was completely absent. Any conclusions must therefore be tempered by the basic mass of variables and unknowns entered into the problem.

b. The Marshall Islands fallout radiation victims, injured as a consequence of an unpredicted yield change of the detonation of a thermonuclear device on Bikini Atoll in March 1954, are the second largest group. Included with the natives of the islands are 28 American servicemen and 23 Japanese fishermen, for a total of 290 persons. Unlike the Japanese group, the Marshall Islanders' clinical courses are very well documented, and a close approximation of the whole body exposure dose is available. The fact that the maximum dose received (discounting the contact beta particles skin dose) by a relatively small number of the victims was in the vicinity of 175 rad is the major limiting factor on the data from this group.

c. Laboratory and industrial accidents involving approximately 30 individuals in the United States, Russia, and Yugoslavia constitutes a small but extremely valuable group from the viewpoint of medical data. This group is exceptionally well documented and encompasses a range of doses from trivial levels to many thousands of rad. Much useful information has been derived from these accident cases to fill gaps and round out the clinical picture.

d. Clinical radiotherapy (X–ray, radium, and isotopes) provides a large, medically well–documented source of information of variable value. Local radiation therapy used beneficially on many patients over many years has led to the accumulation of a vast knowledge of local injury or effect, but lends little to knowledge of whole body effects.

2–4. ACUTE RADIATION INJURY

An understanding that not all tissues and cells are equally sensitive to radiation injury must be reached to appreciate the different clinical responses to varying doses. Cells which are rapidly growing and dividing, that is, undifferentiated cells, are most sensitive, while those that are fully differentiated are resistant. Certain tissues and cells, including the lymphoid, bone marrow, and Krypt cells at the small intestine are especially sensitive. Accordingly, at moderate doses, injury to them with the resultant under–production or over–production of their products (hormones, specialized

cells, enzymes, etc.), alteration of growth rate of population, or even death of the cells or tissues, predicts the type of clinical response. Other tissues and organs are moderately sensitive to such injury (parenchymal cells of the liver and kidney, vessels, adrenal, thyroid). In higher doses, injury to these cells predominates the clinical picture. Resistant or relatively resistant cells and tissues include nerve cells, bone, the eyes, and muscles. With large prompt doses, injury to these structures becomes manifest before injury to the more sensitive parts has time to reveal itself.

2–5. THE SYNDROME

The acute radiation syndrome follows total body receipt of gamma rays, neutrons, or both. The type and severity of response in man is, of all the variables, especially dose–dependent. In all that follows, it is presumed that all doses are received in a short period of time (i.e., up to 48 hours); the body is "uniformly" irradiated; no significant prior or concomitant injury (including radiation) exists; the dose is known; and the individual is average, i.e., neither excessively resistant nor excessively sensitive to radiation. If these conditions are accepted, the disease which follows irradiation can be classified on the basis of the major tissue, organ, or system injured as follows: (1) no obvious disease to slight symptoms; (2) diseases manifested by obvious injury to the blood and blood forming organs (the hematopoietic syndrome); (3) disease manifested by obvious injury to the organs of the gastrointestinal system (the gastrointestinal syndrome); and (4) disease manifested by obvious injury to the central nervous system (the CNS syndrome). The latter three are the sub–syndromes which amount to medical workload and loss of life.

2–6. NO OBVIOUS DISEASE

No obvious disease implies there is no apparent clinical symptomatology or disability, even though there may be demonstrable alteration of the blood and other tissue on laboratory analysis. The range of absorbed dose for this effect is perhaps 0 to 100 rad. In times of disaster or in the presence of mass casualties, individuals in this category could be used to their normal or even maximum capacity providing further significant radiation exposure close in time to the initial insult is avoided. They require no treatment and certainly no hospitalization. Slight symptoms appear in individuals with doses between 100 to 200 rad; however, moderate rest and self–care will generally suffice for these cases (See table 2–1).

Dose (Range)		0-100 cGy (subclinical range)	100-800 cGy (sublethal range)			Over 800 cGy (lethal range)	
			100-200 cGy	200-600 cGy	600-800 cGy	800-3000 cGy	over 3000 cGy
INITIAL PHASE	Incidence of nausea & vomiting	NONE	5-50%	50-100%	75-100%	100%	
	Time of onset	.....	Approx. 3-6 hrs.	Approx. 2-4 hrs.	Approx 1-2 hrs.	Less than 1 hr	
	Duration	.....	Less than 24 hrs.	Less than 24 hrs.	Less than 48 hrs.	Less than 48 hrs.	Approx 48 hrs.
	Combat effectiveness	100%	100%	Can perform routine tasks. Sustained combat or comparable activities hampered for 6-20 hrs.	Can perform only simple routine tasks. Significant incapacitation in upper part of range. Lasts more than 24 hrs.	Progressive incapacitation following an early capability for intermittent heroic response.	Progressive incapacitation following an early capability for intermittent heroic response.
LATENT PHASE	Duration	.....	More than 2 weeks.	Approx. 7-15 days.	None to approx 7 days	None to approx 2 days	NONE
SECONDARY PHASE	Signs & symptoms	NONE	Moderate leukopenia.	Severe leukopenia; purpura, hemorrhage; Infection; epilation about 300 rads.		Diarrhea; fever; disturbance of electrolyte balance	Convulsions; tremor; ataxia; lethargy
	Time of onset post exposure.	.....	2 weeks or more.	Several days to 2 weeks		2-3 days	
	Critical period post exposure.	.....	NONE	4-6 weeks		5-14 days	1-48 hrs
	Organ system responsible.	NONE		Hematopoietic tissue		Gastrointestinal tract	Central nervous system
HOSPITALIZATION	Percentage	NONE	Less than 5%	90%	100%	100%	100%
	Duration	.....	45-60 days	60-90 days	90-120 days	2 weeks	2 days
INCIDENCE OF DEATH		NONE	NONE	0-80%	90-100%	90-100%	
AVERAGE TIME OF DEATH		.....	.....	3 weeks to 2 months		1-2 weeks	2 days
THERAPY		NONE	Reassurance hematologic surveillance	Blood transfusion, antibiotics		Maintenance of electrolyte balance.	Sedatives

Table 2-1. Radiation dose effect relationship.

2-7. THE "TYPICAL" ACUTE HEMATOPOIETIC SYNDROME

The hematopoietic form of the disease will occur with a clinical severity related to the total dose absorbed in the range of 200 to 800 rad; a range associated with a lethality of from 0 to 100 percent at the extremes. This is the form of the disease which is, or should be, of greatest concern, for it represents injury in which proper treatment may exert considerable influence on its course. Although individual biological susceptibility may dictate the severity of response of the blood and blood-forming tissues at a given dose, the type of response is uniform, and for the most part, predictable. A description of the "typical" hematopoietic form of the syndrome, e.g., that which might be seen in an "average" individual after receiving 300 to 350 rad, provides a basis for understanding the clinical nature of the injury and the alterations that different doses, varying sensitivities, and treatment may make. The typical hematopoietic form of the disease is characterized by four phases: the prodromal phase, the latent phase, the bone marrow depression phase, and the recovery phase (see table 2-1).

a. **Initial Prodromal Phase.**

(1) Immediately following receipt of several hundred rad, e.g., 300 to 350 rad, in our hypothetical victim, even when accumulated in an hour or less, there may be no subjective sensations or objective findings. Within one to several hours, abruptly or gradually, listlessness, fatique, disinterest, or even lethargy appear. (If the subject knows or suspects he has been exposed psychogenic invention or magnification of symptoms may be prominent and may serve to confuse or obscure the sequence of these events). These initial symptoms become increasingly more severe and are associated with headache, anorexia, followed by nausea, and finally, frank vomiting. Maximum severity of symptoms and associated incapacity are reached by the 5th to 8th hour, whereafter "recovery" begins with the complaints disappearing in reverse order of their appearance. Some authorities feel that the severity of nausea and vomiting in the prodromal phase may be directly proportional to the amount of food in the stomach at the time of injury and may be prolonged by attempts to refill it. By the end of the second day or the beginning of the third day, a state of comparative well-being is regained with mild cyclic fatique, in some instances, as the only residual.

(2) Vomiting during the prodrome may be the only symptom of value in estimating the degree of radiation injury, providing good clinical judgment is used in evaluating it and the possibilities of psychogenic overlay are not forgotten. Vomiting that occurs late and is of short duration suggests a lower dose than that which occurs early and is severe and prolonged. In doses between 100 and 200 rad, vomiting may or may not occur. Marshall Brucer, however, admonishes us to remember that "The publicity on radiation accidents has been sufficient to instruct people that they should vomit."

(3) The laboratory findings during the prodromal phase are, from a practical standpoint, limited to alterations in the peripheral blood. Although

serial bone marrow studies, mitotic indices, thymidine uptake determinations, examination of the urine for bizarre amino acid content, complicated enzyme studies, examinations of hair roots, and determinations of changes in platelet structure and number are possible, and might contribute individually or collectively to information desirable for dose determination, prognosis, and specific therapy, they represent laboratory maneuvers of considerable difficulty. Whether such expert technical assistance in adequate volume to be useful would exist in a mass casualty situation is doubtful.

(4) The earliest changes in the peripheral blood involve a decrease in the lymphocyte count, occurring within hours, and fluctuations in the total white cell count, with probably a mild overall increase in the white blood cell count during the first few days. Since baseline counts will not have been established, this fluctuation or mild elevation of the total count will have little or no diagnostic or prognostic value. On the other hand, the early lymphopenia is at least suggestive of radiation damage. It is pronounced with high doses and less remarkable with low doses. Experts disagree concerning the value of specific lymphocyte counts in prognosticating. All agree, however, that a rising count after the first few days is an exceptionally good sign.

(5) In summary, the prodromal phase of the hematopoietic form of radiation illness is a 2- or 3-day period characterized by signs and symptoms similar to those of motion sickness, and the laboratory findings are those of nonspecific mild leukocytosis with a relative and absolute lymphopenia. True diarrhea, contrary to earlier descriptions of the syndrome, is not characteristic of the hematopoietic form of the disease.

b. **Latent Phase.** The latent phase begins on the third or fourth day, depending, of course, on the severity of the initial reaction. It persists for about 3 weeks from the time of exposure and is characterized by a remarkable freedom from symptoms. In a few individuals, persistent mild recurrent fatigue may disturb this deceivingly benign period. The laboratory findings in the early part of the phase, at least, also fail to suggest the severity of the disturbances to come. There is a progressive decrease in the total white cell count which is moderate for granulocytes and pronounced for lymphocytes. Near the end of the second week after exposure (12 to 18 days), the severity of the clinical course is disturbed by epilation—loss of hair in large quantities—an event which, from the patient's point of view, is of tragic significance. Since epilation occurs with exposures to more than 300 rad, the sign is of significance only insofar as it attests to the probability that the dose was at least that high to the parts that epilate. All body and head hair is subject to loss following a large enough dose of radiation, but the hair of the eyebrows and eyelashes is apparently less sensitive than that of other parts of the body surface. Except for the psychological trauma associated with this loss of hair, the subject continues to feel well and is able to perform his normal duties. In summary, the latent phase of the hematopoietic form is one of benign clinical course, associated with epilation in exposures exceeding 300 rad, and characterized hematologically by marked lymphopenia.

c. **Symptomatic Phase or Bone Marrow Depression Phase.**

(1) The bone marrow depression phase is heralded during the third week (18 to 21 days) by the return of signs and symptoms suggesting, at first, the onset of an acute infectious process. Chills, feverishness, malaise, increased fatigability, and pharyngitis interrupt the heretofore symptom-free interval. Within the next few days the clinical picture deteriorates rapidly causing the patient to be hospitalized or, at least, confined to bed. The oropharynx becomes swollen with the gingiva (gums) and tonsillar areas showing the most marked reaction and beginning ulceration. As the disease progresses, a tendency to bruise easily or to bleed slightly from the gums (pink toothbrush) appears. Coincident with these findings in the mouth and on the skin, the general condition of the patient reflects the compromise that has affected his blood-forming organs. Streplike fever suggests septicemia and petechiae (pinpoint hemorrhages) and ecchymoses (black and blue areas) may involve broad zones of the skin. (In those patients who do not survive beyond this point as a result of the disease itself or another associated injury, these hemorrhagic phenomena can be shown to involve the lining and coverings of internal organs). Despite earlier predictions based on Japanese bomb casualty data, gross hemorrhage from the orifices and into the interior of the hollow organs will not be massive and continuous, but will be generally self-limiting.

(2) The return of clinical illness and the signs, symptoms, and laboratory findings associated with it, define, rather precisely, the classical picture of acute aplastic anemia. The continuous fall in white cells and platelets, the ulcerations of mucous membrane, the septicemia and bacteremia from the breached defenses of the gastrointestinal tract lining, superimposed upon the inability of the white cell compartment to combat infection, present the serious clinical picture associated with severe bone marrow injury.

(3) In the "typical" case these symptoms and findings reach a maximum severity between the fourth and fifth week, the critical period. Thereafter, recovery begins, manifested by gradual return of the temperature toward normal healing of the ulcerations of the mouth, throat, gums, clearing of the hemorrhage in the skin and mucous membranes, and beginning regrowth of lost hair. These improvements in general are a reflection of the return of bone marrow function with increase in the white cell components of the blood toward normal levels. Return of the lymphocytes, however, is very slow, and many months may pass before normal counts are observed. At this level of radiation, it can be anticipated that sperm production in the male and ovulation in the female of appropriate age will have ceased; return of these functions will not occur for a period of months.

(4) In summary, the bone marrow depression phase of the syndrome is characterized by severely reduced numbers of white cells and platelets in the blood and marrow, due to interference with their production. The picture is one of aplastic anemia with its attendant bleeding phenomena and tendency toward infection. The course is serious to grave to fatal depending on dose,

susceptibility, and treatment. Death, when it occurs, usually intervenes at about the second month, and is due generally to uncontrolled, overwhelming infection.

d. **Recovery Phase.**

(1) The recovery phase is, as the name implies, that period during which the clinical and laboratory alterations, having reached their maximum of severity during the bone marrow depression phase, continue to improve until a state of relative normalcy obtains. The period is of varying length, up to 3 to 6 months, depending on the degree and duration of aplastic anemia, dose, individual response to treatment, and presence or absence of associated injury or major complication. Such major complications as pneumonia, multiple abscess formation, and bacterial resistance to available antibiotics can be expected to occur in a significant percentage of individuals, especially in a mass casualty situation.

(2) In the dose range 100 to 200 rad, where clinical observation rather than actual hospitalization and specific therapy will be the rule, recovery for all can be anticipated. In other words, the prognosis is excellent and can be confirmed on the basis of numerous human cases.

(3) In the dose range 200 to 600 rad, in which about 40 well-documented cases have occurred, the prognosis for recovery is generally good. Treatment in this range, especially at the upper extreme, may play the determining role in recovery. At the level of 600 rad, the LD 50 for man is approached, according to the proponents of high values for the 50-percent mortality dose. Equally competent authorities, extrapolating from available human data and animal experimentation, feel that 600 rad represents the near LD'100 for man, and that 450 rad, or even lower, is the appropriate LD 50.

(4) In the dose range 600 to 800 rad, prognosis must be guarded. Treatment may improve chances for survival considerably in the lower part of the range, but as the upper limits are reached, the situation is increasingly hopeless until at 1,000 rad all, or nearly all, can be expected to die. Brucer's remark that the "area of immediate interest to physicians lies between the 100 and 800 rad levels. Above this level we are helpless and under this level, we are unnecessary," best describes the current philosophy.

(5) In summary, the recovery phase, and convalescence which follows, consumes several weeks to many months depending on dose, response to injury and treatment, and demands to be placed on the survivors. In low ranges, it is rapid and short, and at the upper extreme, prolonged if it is reached at all. It must be emphasized that the form taken by the disease is dose dependent, but not sharply dose dependent as the extremes of each range are approached. For example, at 800 rad the bone marrow injury will continue to predominate the clinical picture, but evidence of injury to the gastrointestinal tract, described below, may begin to appear. There is, in other words, overlap of one form with another at appropriate doses.

2–8. GASTROINTESTINAL SYNDROME

The gastrointestinal form of the acute radiation syndrome is seen when the acute dose has been between 800 and 3,000 rad, and is associated invariably with a fatal outcome. The prodromal phase is more abrupt in onset, violent in character, and prolonged in duration when compared to the hematopoietic form. Diarrhea is characteristic of the prodrome in this form of the disease. The prodromal signs and symptoms finally subside after several days and a short latent period follows. After a few days the symptoms of nausea, vomiting, diarrhea, and fever recur with increased fury, and death as a result of gross electrolyte and fluid balance defects results within 2 weeks. Frank hemorrhage and epilation do not occur because the course of the disease is too short to permit these events to develop. The blood changes seen parallel those found in the high dose range of the hematopoietic form. Treatment, when the patient survives long enough to reach an agency capable of providing it, is palliative. With time and increased knowledge, beneficial therapeutic intervention may improve and prevent hopeless prognosis held for victims of this form of the disease (see table 2–1).

2–9. CNS OR CEREBRAL FORM

The cerebral form of the acute radiation syndrome is seen when the dose has exceeded 3,000 rad. Death within hours can be anticipated. A state of extremes is almost coincident with the time the total dose is received. Symptoms suggesting mortal insult to the brain and cord are predominant, and include explosive, transient nausea, vomiting, and diarrhea. Except for a prompt fall in lymphocytes, which may essentially disappear from the peripheral blood, the findings of leukopenia, bleeding, epilation, and infection, characteristic of the hematopoietic form, do not have time to occur. Irrational behavior, circulatory collapse, and neuromuscular discoordination occur within minutes. There may be some facultative recovery within hours, depending on dose and therapy instituted. Within a very short time, irrational behavior recurs with convulsions and coma preceding death 2 hours to 2 days (see table 2–1).

2–10. FIELD DIAGNOSIS

Any good public health or preventive medicine officer, upon receiving a group of patients from one local area exhibiting prodromal symptoms, would immediately suspect an outbreak of food poisoning. In case of an actual nuclear situation, if you were within range of direct prompt radiation, it would be impossible to be unaware of the detonation. It would however, be possible to be in a fallout field, as were the Marshall Island natives, and remain totally unaware of exposure. From this you can see that the basis for diagnosis is awareness that an exposure has occured. Once it has been determined that people in a certain area were probably or possibly exposed, then the problem is of determining who was exposed and how much radiation did they receive. The prodromal symptoms observed with particular attention to severity and rapidity of onset will give a crude measure to distinguish perhaps tenfold differences in exposure, that is, to separate a 100 rad, 1,000 rad, or 10,000 rad case. A dosimeter or other radiation dose measuring device, may be available to aid in estimation of dose; however, caution should

be used since individual instruments may be broken or malfunctioning, causing erroneous readings. Any individual having recent high dose exposure, i.e., over 100 rad within the last few weeks or months, may show abnormal severe symptoms due to residual damage from previous exposure. Further examination, observation, and laboratory tests of limited or no immediate value in the field will be of use to confirm early diagnosis. Altogether, the pieces will form a picture which will allow approximation of dose and thereby estimation of the injury to a group or individuals. In summary, early and severe onset of symptoms in individuals known to be exposed to radiation, together with dose reading from several instruments in the area of exposure, will allow a diagnosis of radiation injury.

2—11. TREATMENT

a. Since there is no specific acute major pathology and no clearly understood reversible physiological, biochemical, or biophysical event or series of events, there is no specific therapy for acute radiation injury. Time and accumulated knowledge may eventually invalidate this statement, but it is currently true. In the dose range of the cerebral form of the disease (3,000 rad or more), it can be anticipated, in major disasters resulting from thermonuclear yield weapons, that most individuals receiving their doses promptly will also be grievously injured by thermal or blast effects and will not survive long enough to be rescued. (For low—yield tactical weapons, high dose pure radiation injuries are possible.) For those who acquire such large doses over a longer period, as in a fallout field, hospitalization may possibly be accomplished, but treatment will be ineffective.

b. In the range of doses likely to produce the gastrointestinal form of the disease (800 to 3,000 rad), patients in number may survive long enough to be hospitalized and receive early supportive therapy. The situation in a treatment facility with respect to numbers of other casualties of different types, availability of supplies and personnel, and the presence or absence of associated injuries in the radiation victim will determine how much treatment is received. At the present state of the art, it is agreed that, although intelligent fluid and electrolyte replacement may postpone the fatal outcome, it is unlikely that such an outcome can be avoided.

c. In the dose range below 100 rad, no treatment in mass disaster will be indicated, or available. In the range of 100 to 200 rad, clinical observation and reassurance may be all that is necessary. In sensitive individuals and those with associated injuries, hospitalization and treatment may be necessary in doses between 200 and 250 rad.

d. It is in the range of 250 to 800 rad in which intensive treatment correctly anticipated through understanding of the clinical sequence, and given at the appropriate time, can be expected to exert the greatest beneficial influence. Below 500 rad, treatment will ordinarily be conservative and will be directed primarily at the complications associated with the radiation injury (e.g., infection). Above 500 rad, where the prognosis becomes more and more unfavorable, a more radical approach is indicated wherein therapeutic procedures must be given in anticipation of signs and symptoms that have not yet become manifest. Injury directly related

to the radiation effect itself can be expected to proceed rapidly to a clinical climax. Manifestations of such insult include rapid, severe reduction in circulating white cell components, and fluid and electrolyte losses through severe persistent vomiting, and at high doses, diarrhea.

e. The limitations of time and space, and the sheer magnitude of the problem, make it impossible to discuss treatment under all conceivable circumstances. A review of the procedures recommended under "ideal" conditions will enable one to predict the variations and compromises that may be necessary in a given environment. In mass disaster where dose determinations may not be practical, treatment and hospitalization may have to await the development of symptoms.

f. During the first few hours (prodrome), patients estimated to have received more than 250 rad should be hospitalized. Severe early vomiting and skin erythema suggest high doses, and treatment or withholding of it in favor of others may have to be decided early. If there is an associated neutron exposure and if facilities are available to make measurements, a determination of induced sodium radioactivity may contribute to dose estimation. Sedation and the use of antiemetic drugs as indicated are the procedures available in the earliest stages. Psychological vomiting in the lower doses is, however, not managed by antiemetics. Fluid and electrolyte replacement in cases of severe vomiting may be necessary early. Brucer asserts, during the early phase, "Probably the most important therapeutic procedure that can be performed during the first few hours is to resist the temptation to load the patient with blood, drugs, and synthetic metabolic poisons."

g. During the first few days, a definite pattern develops which should enable one to distinguish between high-dose and low-dose victims and to make appropriate determinations insofar as further supportive measures are concerned. In those for whom a distinct bone marrow depression can be predicted or anticipated, planned management must follow.

h. At the beginning of and throughout the latent phase, there is no special indication for treatment. Patients, if they have been hospitalized, should remain there during this period. The situation may, however, require that they be discharged to await further developments. It must be emphasized that the serious events presenting the greatest therapeutic challenge do not appear, except in high-dose victims, until the second or third week.

i. The bone marrow depression phase with its attendant problems of bleeding and infection is managed by the judicious use of fresh whole blood, if available, and broad spectrum antibiotics given when indicated and not prophylactically. The desirability of giving only platelets and white cell extracts of whole blood to patients with an adequate red cell count is obvious, but the ways and means of fulfilling this desire are not available, particularly with large numbers of patients.

j. Bed rest, good nursing care, a nourishing easily digested diet, and anticipation of complications constitute the remaining therapeutic activities. Nothing specific is available to reverse or minimize radiation effects. There are no emergency or heroic measures known. Final success or failure when

faced by a nuclear situation will rest on thoughtful planning prior to the situation along with efficient management of the medical problems resulting from the nuclear detonation.

EXERCISES, LESSON 2

REQUIREMENT. The following exercises are to be answered by marking the lettered response that best answers the question; or by completing the incomplete statement; or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson, and check your answers with the Academy solutions.

1. Which of the following has the greatest influence in the response of an irradiated victim?

a. Type and energy of the radiation.

b. Time during which radiation is received.

c. Presence or absence of associated injury.

d. Total dose received.

2. List the sources of human data concerning nuclear radiation.

_____

_____

_____

_____

3. In whole body irradiation, which of the following is the most critical tissue to be shielded?

a. Nerve cells.

b. Bone marrow.

c. Adrenal.

d. Muscles.

4. In adults, which of the following listed tissue types is the most radioresistant?

a. Muscle tissue.

b. Bone marrow.

c. Spermatocytes.

d. Lymphoid.

5. The type and severity of response in man to the acute radiation syndrome is especially dependent upon _____.

6. List four classfications of the acute radiation syndrome.

_____

_____

_____

_____

7. About what is the range of the absorbed dose in the classification of "no obvious disease ?"

_____

8. What classification of the acute radiation syndrome should you associate with the dose range of 200 to 800 rad?

_____

9. Which classification of the acute radiation syndrome represents the radiation injury for which treatment can do the most?

_____

10. List four phases of the typical hematopoietic form of the radiation syndrome.

_____

_____

_____

_____

11. One would expect to see the gastrointestinal form of the acute radiation syndrome when the acute dose is between _____ and _____ rad.

12. Which of the following describes the treatment provided for a patient who has received a short-term, whole body exposure in excess of 800 rad?

a. Therapeutic intervention.

b. Palliative.

c. Emergency.

d. Intensive.

SOLUTIONS TO EXERCISES, LESSON 2

1. d (para 2–2a)

2. Japanese bomb casualties, Marshall Islands, laboratory and industrial accidents, and clinical radiotherapy. (para 2–3a–d)

3. b (para 2–4)

4. a (para 2–4)

5. Dose dependent. (para 2–5)

6. No obvious disease; hematopoietic syndrome; gastrointestinal system; and CNS syndrome. (para 2–5)

7. 0–100 rad (para 2–6)

8. Hematopoietic syndrome (para 2–7)

9. Hematopoietic syndrome (para 2–7)

10. Prodromal; latent; bone marrow depression; and recovery. (para 2–7a–d)

11. 800–3000 (para 2–8)

12. b (para 2–8)

LESSON ASSIGNMENT SHEET

LESSON 3	--Comparative Effects of Nuclear Weapons; Residual Radiation Dose and Decay Calculations; and Management of Mass Casualties.
LESSON ASSIGNMENT	--Paragraphs 3-1—3-18. Turn to Appendix A and study the nomograms in GR 76-332-100.
MATERIALS REQUIRED	--ABC-M1 radiac calculator. On the inside rear cover of the subcourse is a printed simulated ABC-M1 radiac calculator. Cut out and assemble with pin, plotting needle, or thumbtack to solve the problems in this lesson.
LESSON OBJECTIVES	After completing this lesson, you should be able to:

3-1. Estimate type and extent of casualty producing hazards of various yields of weapons.

3-2. Calculate radiological dose and decay, using nomograms.

3-3. Recognize ABC M-1 Radiac calculator.

3-4. Discuss categories of patients resulting from mass casualty situations.

SUGGESTION	--After completing the lesson assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 3

COMPARATIVE EFFECTS OF NUCLEAR WEAPONS; RESIDUAL RADIATION DOSE AND DECAY CALCULATIONS; AND MANAGEMENT OF MASS CASUALTIES

Section I. COMPARATIVE EFFECTS OF NUCLEAR WEAPONS

3–1. GENERAL

With the exception of residual radiation, the effects of a nuclear weapon occur simultaneously. It is, therefore, appropriate to discuss the integrated or combined effects of nuclear weapons. At any given location from ground zero, one can determine the effects which are acting simultaneously to produce casualties. The various weapon effects may be compared using the casualty criteria below as a basis. No attempt has been made to evaluate the synergistic effect of two or more casualty–producing mechanisms acting on a human target.

EFFECT	CRITERIA
Blast	3–5 psi—For personnel in open, 50% probability of serious wounds from 10g glass fragments in 3 meters of travel (Impact velocity 55 meters/second). 5 psi—Threshold for eardrum rupture. 5–10 psi—50% probability of lethality from displacement in 3 meters of travel (Impact velocity 8 meters/second). 22 psi—Foxhole collapse (50% filling)
Thermal Radiation	4–10 cal/cm^2—2d° burns on exposed surfaces. 7.5–20 cal/cm^2—50% probability of burns under summer uniform. 10–26 cal/cm^2—50% probability of burns under winter uniform.
Nuclear Radiation	650 Rad—Nausea and vomiting within 2 hours (100%) 3000 Rad—Nausea and vomiting within 5 min. (100%)

Table 3–1. Casualty criteria for personnel exposed to prompt effects.

3–2. GOVERNING EFFECT

a. Table 3–1 illustrates the relative importance of the three initial effects in the production of casualties as a function of range for various explosion yields. The areas included within the radii which represent the 2 hour (650 rad) and 5 min 100% (3,000 rad) sickness doses of ionizing radiation are relatively small and do not increase significantly as the weapon yield increases. Due to the manner in which ionizing radiation is degraded by distance, these radii of effects do not extend much beyond 2,500 meters (1.6 miles) even for a one megaton weapon. A thousandfold increase in yield extends the range only by a factor of 3. The radii for blast effects do show a significant increase with weapon yield. For serious missile injuries (50 percent probability) it can be seen that the range increases by a factor of 11 and for displacement injuries (50 percent probability of lethality) by a factor of 15. The thermal effects radii portray the distances within which second degree burns will occur on exposed skin and under the uniform. Table 3–2 demonstrates a dramatic increase in this range of 2° burns when the weapon yield is increased. For a one megaton weapon, 2° burns on exposed surfaces extend out to approximately 17,700 meters (11 miles) and include an area of about 984 square kilometers (379 square miles). For 2° burns under the winter uniform (50 percent probability), the range is 8,370 meters (5.2 miles).

Casualty criteria	Yield			
	1 KT	10 KT	100 KT	1 MT
	(Distance in meters)			
50% probability of serious wounds (glass fragments).	740	1610	3860	8530
50% probability of lethality or displacement impact.	450	1130	2900	7080
Foxhole collapse (50% filling).	270	580	1260	2730
2° burns on exposed surfaces.	805	2415	6440	17,700
2° burns—50% probability under summer uniform.	580	1480	3700	9330
2° burns—50% probability under winter uniform.	515	1200	3380	8370
650 Rads (Nausea and vomiting within 2 hours).	840	1290	1770	2570
3000 Rads (Nausea and vomiting within 5 min).	580	970	1530	2090

Table 3–2. Comparison of weapon effects (airbursts).

b. With the lower yield weapons, nuclear radiation injuries, compounded by mechanical injuries, will probably represent the predominant type of casualties. On the other hand, with the higher yield weapons, burns, wounds, and combinations thereof will represent the predominant types of injury from the initial effects. In a fallout area, nuclear radiation injuries will constitute the main medical problem.

3–3. DETERMINATION OF EFFECTS BY USE OF NOMOGRAMS

a. **General.** In order to make the various calculations of weapon's effects for the variety of weapon yields and height of burst, the nomograms found in Appendix A, GR 76–332–100 may be used. In each of these nomograms there are columns of data. There is, in general, a yield column on the left of the page, a distance or radius of damage column in the center, and some effect on the right. As with any nomogram, the procedure is to enter with two known values to determine some unknown value. For example, if one takes a low airburst (p. A–40), 10 KT weapon, and determines the effect at 1000 meters, he would find that there would be 6.4 psi overpressure with severe damage to brick apartment houses. This was obtained by placing the hairline, or any straightedge, through the values 10 KT and 1,000 meters on the left and center scale respectively, and reading the effect on the right–hand scale under psi and severe damage. Particular caution should be used with the blast nomogram to be sure that the right page is used. That is, if one is calculating effect from a low airburst, use the nomogram headed by Blast Damage Low Airburst. Similarly, one must be careful in using the nomogram on thermal radiation so that proper values are entered into the center column for surface or air burst.

b. **Distance Column of Nomogram.** The distance column in the center of the nomogram may be headed radius of damage or distance. The term "radius of damage" is a more general term for distance; that is, the radius of damage defines a circle each part of which will, of course, be equal distance from ground zero, thereby defining all points of equal damage. Interest generally is in only one point on that circle; this is referred to as the distance from ground zero. For these calculations for low air and surface burst, the distance to GZ will be the distance for entry into all of these effects nomograms. The best way to gain proficiency in the use of any technique is practice. For this practice, a set of calculations of weapons' effects have been provided and from this a comparison of various parameters of yield, height of burst, distance of effects, and protection of personnel can be derived.

c. **Problem 1.** Compare the effects of a 10–KT weapon at 1,000 meters distance. By using information found on pages A–39,40,41,42, in Appendix A, GR 76–332–'00, you will find the following:

	Blast psi	Thermal Cal/cm²	Rad Dose
Low Air Burst	6.2	26	1600
Surface Burst	5.0	6	1600
Subsurface Burst	Neg	Neg	Neg

(NOTE: There is no nomogram for determining the effects of a subsurface burst, but we know that a major portion if not all (depending on the depth of the burst) of the initial effect will be absorbed by the ground. We will expect little or no atmospheric blast, heat, or radiation from a subsurface burst. Keep in mind, however, that a near surface subsurface burst, while being minimal in prompt effects, will produce a heavily contaminated area around ground zero as well as a significant fallout field downwind from the burst. Considering not only that fallout is to be avoided but also the magnitude of the prompt effects, it can be readily seen why the low airburst is the tactical weapon of choice. In every case it is superior or, at least, equal to the surface burst in prompt effects.)

d. **Problem 2.** In this problem we will compare the effects of various yields of weapons against unprotected personnel. For a low airburst, determine the distance to which each of the following effects will extend by actually finding the following information in Appendix A, GR 76-332-100, pages A-39,40,41,and 42.

	Blast 6 psi	2° burn	500 Rad
.5 KT	_____	_____	_____
1 KT	_____	_____	_____
10 KT	_____	_____	_____
100 KT	_____	_____	_____
1 MT	_____	_____	_____

Check your findings with the findings given below.

	Blast 6 psi	2° burn	500 Rad
.5 KT	380 m	580 m	700 m
1 KT	480 m	770 m	800 m
10 KT	1,000 m	2,100 m	1,200 m
100 KT	2,200 m	5,500 m	1,700 m
1 MT	4,600 m	14,500 m	2,400 m

In this comparison, it can be seen that radiation (rather than blast and second degree burn) will cover the largest area with casualty producing effects in yields of 1 KT or less. In large yields the thermal effects will be the most extensive.

e. **Problem 3.** In this problem, we will compare the effects of nuclear weapons against personnel in protected positions; i.e., foxholes. In this case use 2,000 rad in the open as a casualty producer in the foxhole, since one-fourth of the outside dose rate will penetrate into the foxhole (prompt effects). Ten percent of fallout will penetrate the foxhole. For a low airburst, determine the distance to which each of the following effects will extend. Consider the personnel to be shielded in a standard 6' foxhole.

	Blast	Thermal	2000 rad in open 500 rad in foxhole
.5 KT	_____	_____	_____
1 KT	_____	_____	_____
10 KT	_____	_____	_____
100 KT	_____	_____	_____
1 MT	_____	_____	_____

Check your findings with the findings given below.

	Blast	Thermal	2000 rad in open 500 rad in foxhole
.5 KT	200 m	None	520 m
1 KT	250 m	None	610 m
10 KT	530 m	None	960 m
100 KT	1,150 m	None	1,340 m
1 MT	2,500 m	None	2,090 m

The thermal effect is totally blocked by the foxhole. Both the blast and radiation are reduced by the protection of the foxhole; but when we compare the effects with the results of the previous problem against personnel in the open, we see that the blast casualty effect is reduced to about one-half its range in the open where radiation is reduced to a much lesser degree. The result is that against protected personnel, the radiation may be a serious hazard even in yields of over 100 KT. We would, therefore, expect to see a large number of radiation casualties in protected personnel close in to a relatively large nuclear burst where there might be limited or no other injuries present. Nuclear radiation is unquestionably the most difficult of the three prompt effects to shield, and thermal radiation is by far the most readily blocked.

f. **Problem 4.** If given a finite parameter of weapons effects and the yield or distance from the burst, you can determine what other effects would be expected on the same location. For example, if you are given that skin reddening has occurred in your area and that rotted wood has been ignited and you are 2,000 meters from ground zero of a low airburst, you can then proceed to determine what other effects may be present. First, the yield must be determined by entering the thermal nomogram with the known parameter of effect and known distance. This will determine a yield of about 6.5 KT (Appendix A, GR 76-332-100, p. A-41). With the yield of 6.5 KT and distance of 2,000 meters, now the other effects can be determined. The blast effect would be 1.8 psi (Appendix A, GR 76-332-100, p. A-40) which would produce no serious casualties. There would also be a combined initial nuclear radiation dose (total dose) of 10 rad (Appendix, A GR 76-332-100, p. A-42). This would also produce no serious casualties.

g. **Problem 5.** Given: a nuclear low airburst of relatively small yield was detonated approximately 1,000 meters from your location. Wood frame structures were severely damaged; two aircraft parked nearby were not seriously damaged. What degree of burn would you expect to develop and what

radiation dose did your people probably receive? Using the observed effects and distance in the low airburst blast nomogram, the yield is determined to be 2.5 KT (Appendix A, GR 76-332-100, p. A-40). This would result in 5.6 cal/cm2 (p. A-41) and 350 rad total dose (p. A-42). The thermal would not produce any significant casualties, but the radiation dose would very definitely produce serious problems--probably in about 3 weeks when severe anemia would be present. This unit would be a loss at that time.

3-4. CASUALTY ESTIMATION

Having reviewed the relative effects of different weapons under a variety of sets of parameters, we can now turn to casualty estimation. In order to estimate the type of casualty to be expected, we must first determine the radius of damage for the casualty-producing effect for a particular weapon of interest. If the unit in question is found to be within that distance we can expect to see the particular type of damage or injury. For example, members of a unit located 500 meters from a 1 KT burst would have at least 2o burns on exposed skin and would receive a serious dose of radiation, since they are well within the range of these effects. They would receive only moderate blast injuries because they are beyond the range of severe damage or blast effect in the open (Appendix A, GR 76-332-100, p. A-40).

3-5. SUMMARY OF EFFECTS

a. The type of burst will affect the casualty production by altering the range of the effect in the air. Surface bursts have somewhat less effect than airbursts, and subsurface bursts have considerably reduced effects or perhaps no atmospheric effect at all.

b. The disposition of troops in protected positions will affect the casualty picture. In general, it will markedly reduce the number of injuries at any given distance. The amount of reduction will be different, however, for each of three effects. The thermal effect will be totally eliminated at any reasonable distance of interest. The blast effect will be reduced to approximately half the radius of damage for personnel without protection. The radiation is the most difficult to shield and is reduced to a lesser degree than the blast. We would, therefore, know that personnel in foxholes or underground shelters would not have thermal injuries and, if located relatively close in to a nuclear burst, might have ionizing radiation injury alone or a combination of radiation and blast injuries.

c. In general, it can be said that for unprotected troops, weapons of 1 KT or less will have initial ionizing radiation as their greatest casualty-producing effect. Under the same condition, it can be expected that thermal injury will be the most extensive for large-yield weapons, particularly up in the megaton range. With large-yield nuclear weapons, fire starting capability and flash burns will undoubtedly be the greatest hazard.

d. Estimation of the number of casualties may be quite difficult; however, certain facts can help us in making an estimated determination of numbers. Certainly a unit beyond the radius of damage for any injuring effect would have no casualties. Equally certain, any unit located right in the

ground zero area of a burst will have a high percentage of lethal casualties, and relatively few hopeful patients. The difficult area for estimation of numbers or percentage of a unit injured lies in the area of units that are in the margins of the damage range. We can certainly say, though, that a large portion of a unit in the open located at a distance where 3o burns and burns through clothing occur will have thermal injuries. We can also be cautious in our management of burns and blast injuries of troops exposed to a relatively small yield weapon, knowing full well that if they were close enough to get these injuries they must certainly have all received some serious dose of radiation. A large degree of judgment and educated guesswork will have to go into the estimation of number of casualties until an experience factor can lend fact to this area of conjecture.

e. At this point, we have no method currently accepted for field use for the estimation of nuclear battle casualties. With this understanding of the comparative effects and relative range of the effects, however, you should be able to make some reasonable estimate as to the type and perhaps even numbers of casualties you might expect from a given weapon at a given distance.

Section II. RESIDUAL RADIATION DOSE AND DECAY CALCULATIONS

3-6. INTRODUCTION

When it appears likely that we may have to operate in and around a fallout area, it becomes necessary to make some estimates of the radiological decay and possible dose in this area. There are several methods which can be used to make dose and decay calculations, and many decisions may very well be based on these calculations. The radiological contamination in fallout for the most part is a combination of approximately two hundred radioisotopes produced by the fission reaction; we refer to these radioisotopes as fission products. Radioisotopes are unstable isotopes and in order to reach stability, they release energy. The result is ionizing radiation such as gamma rays or alpha and beta particles. Radioisotopes have a half-life; this means that as the radiation is emitted, a percentage of the isotope becomes more stable. This process is referred to as decay. The radioisotope as it releases energy decays to a stable state. The half-life is the time it takes for one-half of the isotope to decay. The significance of this process is that once fallout is complete there is a continuous decrease in the dose rate; initially this decrease is quite rapid but after two days it slows down considerably.

3-7. METHODS USED IN CALCULATING DOSES AND DOSE RATES

There are three methods that can be used to calculate dose rates and total doses. Use of the dose rate and total dose nomograms is the most accurate method, but it requires materials which may not be readily available. A second method is the ABC-M1 RADIAC calculator which is commonly referred to as the "whiz wheel." This method, while not as accurate as the nomogram, is convenient because the calculator can fit into the pocket of the uniform. The

last method for calculating dose rates or total doses is through the application of various "rules of thumb." This is the least accurate method, but it does not require any additional materials in application.

3–8. NOMOGRAMS

One important fact to clear up here is that none of these methods can be used until the peak dose rate has occurred. Turn to page A–12 in Appendix A, GR 76–332–100. The left side of this nomogram has a column heading of Rt. Rt is the dose rate at any time other than H + 1. The middle column (index) represents time of the dose rate (Rt) and accounts for standard decay rates. The column on the right (R1) is the dose rate at H + 1. This figure is "normalized" dose rate and may not reflect the actual H + 1 dose rate, but is used for mathematical convenience in the nomograms. This nomogram can be used then to determine past, present, and future dose rates once the peak has occurred. For example, if we know that at H + 2 the dose rate was 200 rad/hour (the peak dose rate has occurred), what will be the dose rate at H + 3? We first must determine what the R1 dose rate is. Place your hairline or ruler on 200 in the Rt column, and on the two in the index column. You should be able to read approximately 450 rad/hr in the R1 column; this is the normalized dose rate at H + 1. Since we want the dose rate at H + 3, keep the hairline on 450 in the R1 column and rotate the hairline so that it intersects the 3 in the index column. The answer is found in the Rt column and should be approximately 120 rad/hr. Page A–10 has the nomogram that is used to determine doses. Although it will not be demonstrated here, two comments are appropriate. Whenever this nomogram is used, you must always use R1 dose rate. Note the middle index line, this line is for reference only; therefore, in order to use this nomogram you must have values for three of the columns. Given these three values you can determine the fourth unknown value.

3–9. ABC–M1 RADIAC CALCULATOR

a. **Introduction.** The ABC–M1 radiac calculator provides a rapid method of calculating radiation hazards caused by radioactive fallout from a nuclear burst. The following calculations can be made using data from radiological survey reports and other sources:

(1) Decay of radioactive fallout.

(2) Normalizing survey data.

(3) Dose absorbed by personnel exposed to radioactive fallout.

(4) Exit time and length of stay.

b. **Definitions.**

(1) Decay of radioactive fallout. Decay of radioactive fallout is the decrease of radioactivity with the passage of time.

(2) Dose. Dose is the total number of rad which an individual will absorb during the time (exit time minus entry time) he is exposed to radioactive fallout.

(3) Rad. A rad is a unit of absorbed dose.

(4) Dose rate. The dose rate is the number of rad per hour to which personnel will be exposed.

(5) Entry time. Entry time is the actual or planned time personnel enter an area of radioactive fallout. It is expressed as the number of hours elapsed from time of burst (H).

(6) Exit time. Exit time is the actual or planned time personnel leave an area of radioactive fallout. It is expressed as the hours elapsed from time of burst (H).

(7) Normalization of survey data. Normalization of survey data is the process of converting the dose rate obtained from survey at a known time to the dose rate 1 hour after a nuclear burst (H + 1).

(8) Transmission factors. Transmission factors are fractional amounts of radiation which will be transmitted through various types of shelters. The dose or dose rate to which unprotected personnel would be exposed is multiplied by the appropriate transmission factor to obtain the dose or dose rate for personnel protected by a specific shelter.

inside dose/outside dose = (i.e., 50/100 = 0.5, TF = 0.5)

c. **Description**. The ABC-M1 radiac calculator (fig. 3-1) consists of three opaque white laminated plastic disks—an inner disk, ①, an intermediate disk, ②, and an outer disk, ③--mounted concentrically by means of an aluminum rivet.

(1) Inner disk. The inner disk is 1 15/16 inches in diameter. An ENTRY-EXIT TIME AFTER BURST logarithmic scale divided clockwise into minutes, hours, days, and weeks is imprinted in black on the outer edge of the disk. The HOURS and WEEKS portions of the scale are imprinted on a yellow background. That portion of the scale that extends beyond 20 weeks overlays the minutes portion of the scale to halfway between the 9 and 10 MINUTES positions, where the symbol for infinity (∞) marks the end of the scale.

(2) Intermediate disk. The intermediate disk is 3 7/8 inches in diameter. A logarithmic scale divided counterclockwise into minutes, hours, days, and weeks is imprinted in black on the outer edge of the disk. The 1 HR position (H + 1) is imprinted in red. A TIME OF ENTRY index line, ④, is imprinted on the intermediate disk. The index line is used for alining the inner disk with reference to the intermediate disk. Red and black bands on the intermediate disk form a set of red, white, and black guide bands, ⑤, from the scale on the inner disk to the scale on the intermediate disk.

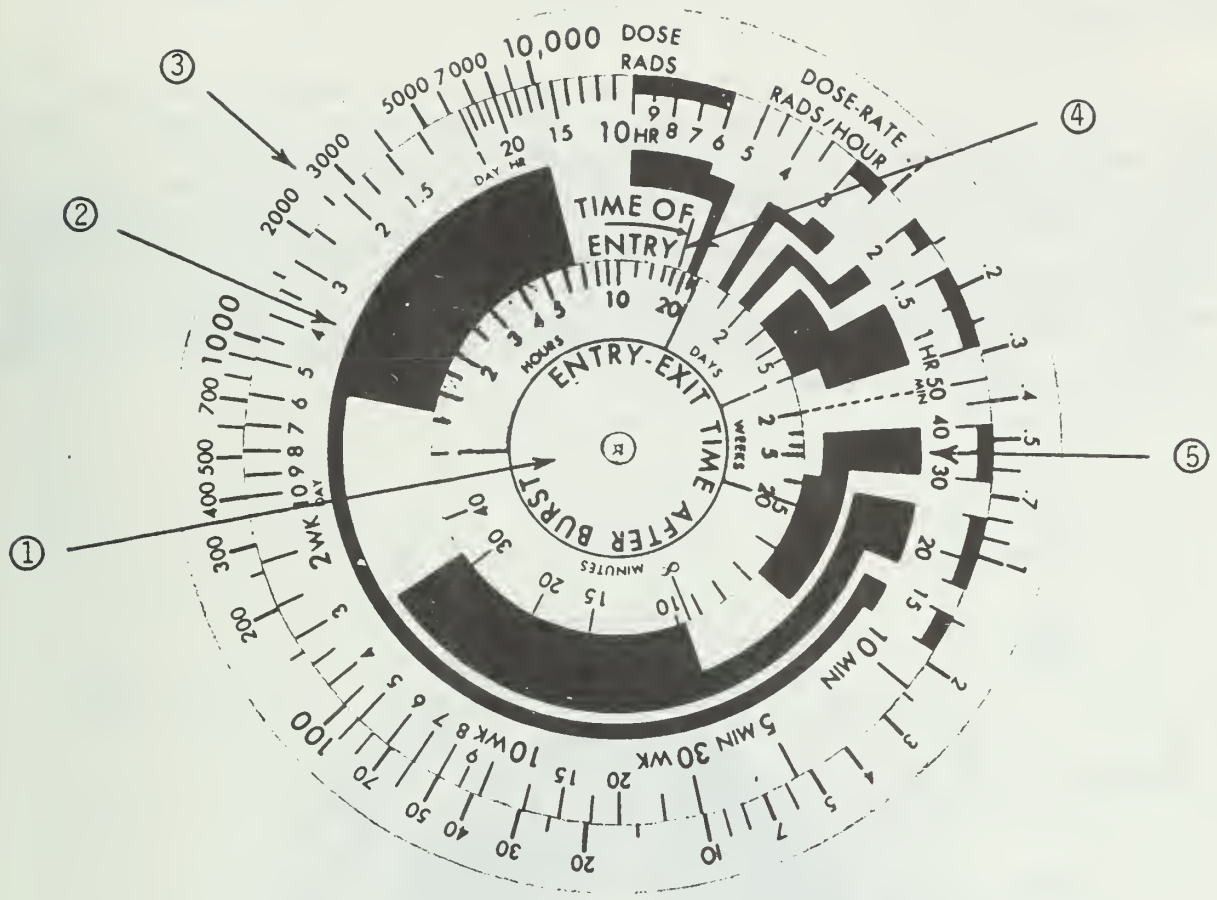


Figure 3–1. ABC–M1 radiac calculator.

(3) Outer disk. The outer disk is 4 1/2 inches in diameter. A logarithmic scale divided clockwise from 0.1 to 10,000 is imprinted in black on the outer edge of the disk. The scale serves to indicate both a dose (in rads) and a dose rate (DOSE–RATE RAD/HOUR).

(4) Instructions. Condensed instructions for use of the calculator to obtain the dose rate and the total dose are printed on the back of the calculator.

(5) Transmission factors. The transmission factors that are printed on the back of the calculator match the transmission factors for the various type shelters which are shown in the Appendix A, GR 76–332–100, page A–8.

d. **Solving Problems.** Examples of the types of problems that can be solved with the ABC–M1 radiac calculator are explained and illustrated below.

(1) Decay of radioactive fallout (fig. 3-2).

(a) Problem. The dose rate reported by a survey team at 2 1/2 hours after burst (H + 2 1/2 hours) was 50 rad/hr. What will the dose rate be at H + 5 hours? When will the dose rate be 2 rad/hr? When will the dose rate be 1 rad/hr?

(b) Solution. Align 50 rad/hr on the DOSE-RATE RAD/HOUR scale with 2.5 hours on the time scale on the edge of the intermediate disk, (1). Read the dose rate on the DOSE-RATE RAD/HOUR scale that aligns with 5 hours (5 hr) on the time scale on the edge of the intermediate disk. The correct answer is 22 rad/hr at H + 5 hours, (2). Read the time on the scale on the edge of the intermediate disk that aligns with 2 rad/hr on the DOSE-RATE RAD/HOUR scale. The correct value is H + 1.5 days, (3), for a dose rate of 2 rad/hr. Read the time on the scale on the edge of the intermediate disk that aligns with 1 rad/hr on the DOSE-RATE RAD/HOUR scale. The correct value is H + 2.75 days, (4), for a dose of 1 rad/hr.

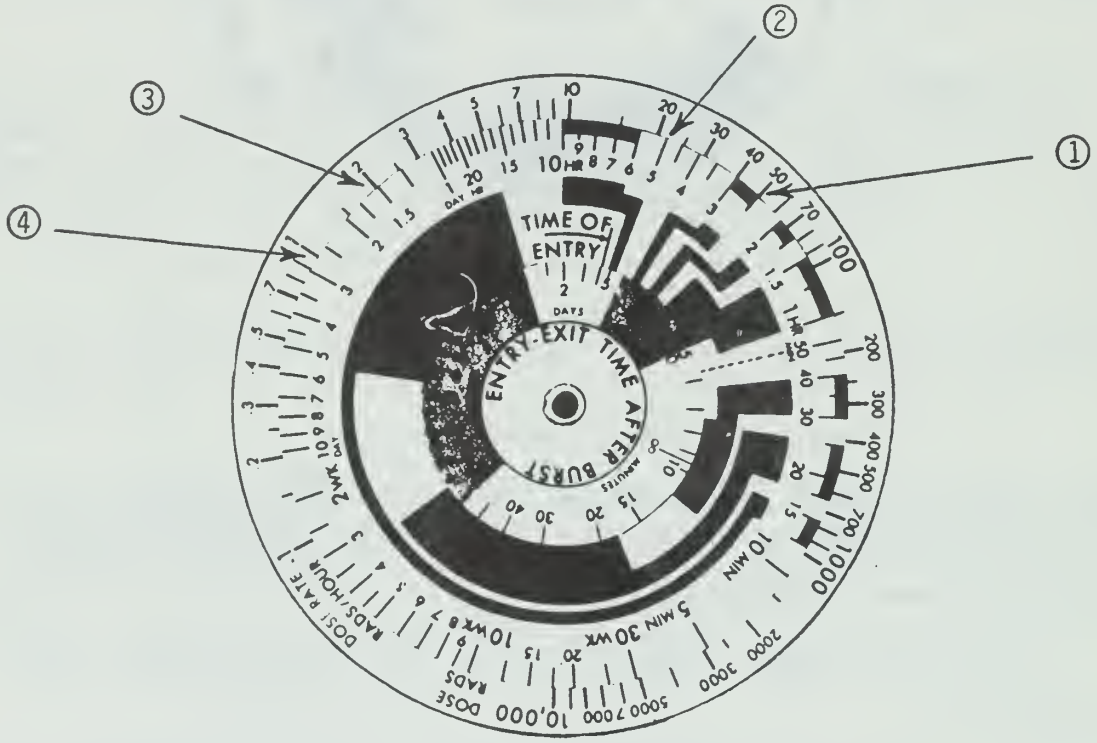


Figure 3-2. Decay of radioactive fallout.

(2) Normalizing survey data (fig. 3-3).

(a) Problem. The following survey readings were reported from units in a fallout area. Normalize the readings to 1 hour after the burst (H + 1).

Unit	Time	Reported dose rate
Co A	H + 2	25 rad/hr
Co B	H + 3	10 rad/hr
Co C	H + 4	15 rad/hr

(b) Solution. To normalize Co A's reported dose rate, align 2 hr on the time scale on the edge of the intermediate disk with 25 rad/hr on the DOSE–RATE RAD/HOUR scale, ①. Hold this setting. Read the dose rate on the DOSE–RATE RAD/HOUR scale that aligns with 1 hr on the time scale on the edge of the intermediate disk. The correct value is 58 rad/hr, ②. Follow the same procedure with the other reported dose rates. Correct normalized dose rates are tabulated on the following page.

Unit	Time	Reported dose rate	H + 1 dose rate
Co A	H + 2	25 rad/hr	58 rad/hr
Co B	H + 3	10 rad/hr	38 rad/hr
Co C	H + 4	15 rad/hr	80 rad/hr

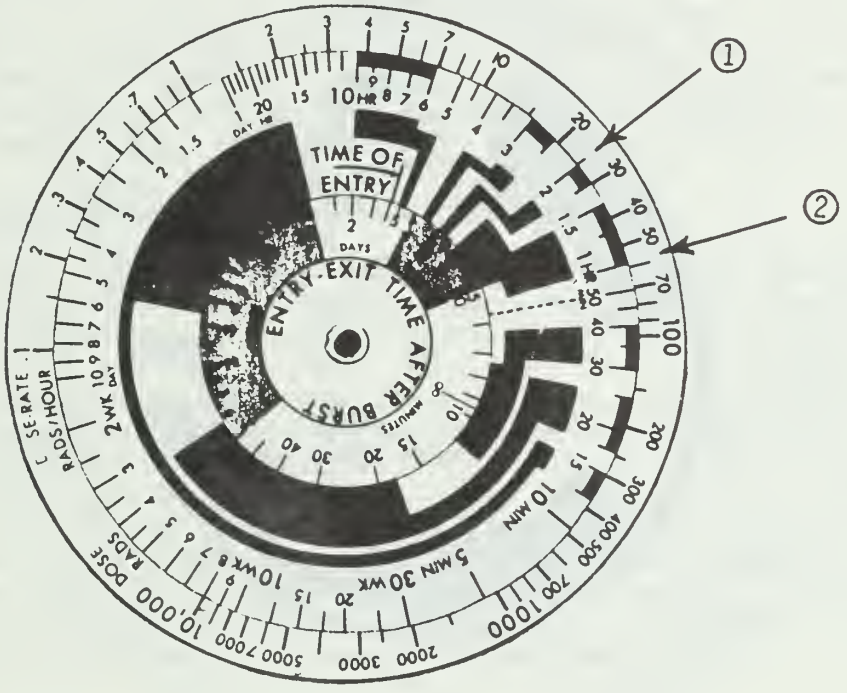


Figure 3–3. Normalizing survey data.

(3) Dose absorbed by personnel exposed to radioactive fallout (fig. 3–4). The following problem assumes no shielding for personnel exposed to fallout.

(a) Problem. The mission of a unit requires that personnel enter a fallout area 5 hours after a nuclear burst and remain in the area for 7 hours. A dose rate of 30 rad/hr was present in the area at H + 1 hour. What is the dose these personnel would receive?

(b) Solution. Align 30 rad/hr on the DOSE-RATE RAD/HOUR scale with 1 hr on the time scale on the edge of the intermediate disk, ①. Hold this setting. Align 5 hours on the ENTRY-EXIT TIME AFTER BURST scale on the inner disk with the TIME OF ENTRY INDEX line on the intermediate disk, ②. Hold this setting. Locate 12 hours, ③, on the ENTRY-EXIT TIME AFTER BURST scale. (This value represents H + 5 hours plus the 7 hours that personnel must remain in the fallout area.) Note the position of the 12-hour line in relation to the white guide band on the intermediate disk. Follow the white guide band outward to the outer disk and read the dose on the DOSE RADS scale on the outer disk. The correct value is 18 rads, ④, which is the same relative position on the intermediate disk with respect to the white guide band as the 12-hour line on the inner disk.

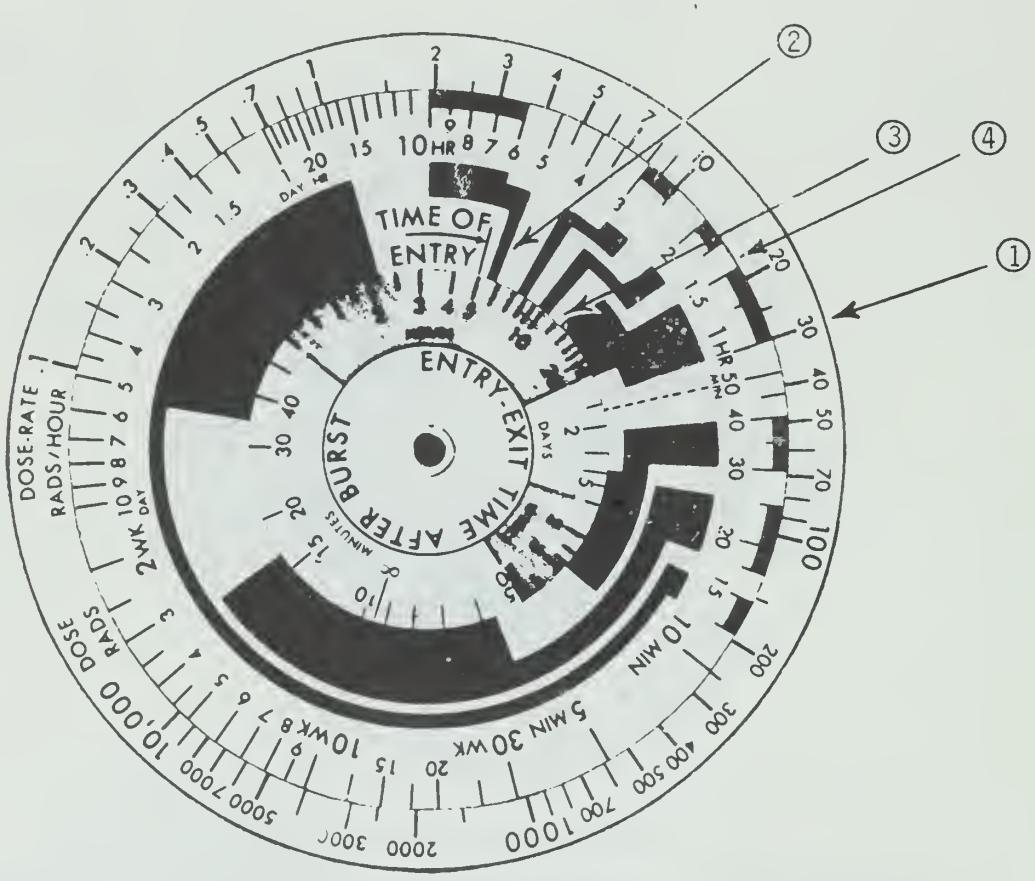


Figure 3-4. Dose absorbed by personnel.

(4) Dose absorbed by personnel in shelters.

(a) Problem. If personnel in unit (3) above enter the fallout area in an APC, what is the dose that personnel will receive?

(b) Solution. The transmission factor for an APC is 0.3. The dose received by unshielding personnel in (3) above was 18 rad. Total dose inside the APC, therefore, would be 0.3 times 18 or 5.4 rad.

(5) Exit time or length of stay. By reversing the order of the procedure used above, exit time and length of stay in a fallout area can be calculated from survey data when a permissible dose is known.

(a) Problem. How long can a unit remain in a fallout area and not exceed a dose of 18 rad if the dose rate was 30 rad/hr at H + 1 and the unit is scheduled to enter the area at H + 5?

(b) Solution. Align 30 rad/hr on the DOSE-RATE RAD/HOUR scale with 1 hr on the time scale on the intermediate disk. Hold this setting and align 5 hours on the ENTRY-EXIT TIME AFTER BURST scale with the TIME OF ENTRY INDEX line on the intermediate disk. Hold this setting. Locate 18 rad on the DOSE RADS scale on the outer disk. Note the position of 18 rad in relation to the white guide band on the intermediate disk. Follow the white guide band inward and read the time on the ENTRY-EXIT TIME AFTER BURST scale that corresponds to the same position on the white guide band as the 18 rad line on the DOSE RAD scale. The reading on the ENTRY-EXIT TIME AFTER BURST scale is 12 hours. At this time H + 12 hours, the unit must leave the area. Since the unit entered the area at H + 5 and must leave the area at H + 12, the allowable length of stay is 7 hours.

(6) Earliest allowable entry time.

(a) Problem. If a reading of 1,000 rad/hr is observed at H + 15 minutes, when can unprotected personnel enter the area and remain for a period of 3 days and not exceed an absorbed dose of 200 rad?

(b) Solution. Align 1,000 rad on the DOSE-RATE RAD/HOUR scale with 15 minutes on the time scale on the intermediate disk. Hold this setting. Manipulate the ENTRY-EXIT TIME AFTER BURST scale until 200 rad on this scale, as indicated by the guide band, aligns with a time in excess of 3 days. Note the time on the ENTRY-EXIT TIME AFTER BURST scale, which is now aligned with the TIME OF ENTRY INDEX line on the intermediate disk. By careful manipulation of the ENTRY-EXIT TIME AFTER BURST scale, it can be determined that troops can enter the area at about H + 11 hours and leave 3 days thereafter and not exceed an absorbed dose of about 200 rad.

3-10. "RULES OF THUMB"

These rules are the least accurate method, but in the absence of any calculation materials they can be useful.

a. The "7–10" rule states that for every seven–fold increase in time, there is a ten–fold decrease in dose rate. If the dose rate at H + 1 is 1,000 rad/hr, the dose rate H + 7 will be 100 rad/hr. If the dose rate at H + 4 is 500 rad/hr, what was the dose rate at H + 28? There is one seven–fold increase so the dose rate would be 50 rad/hr.

b. The second rule is called the "double–the–time" rule. When time is doubled, the new dose rate may be found by dividing the old rate by 2 and subtracting 10% of the result. If the dose rate at H + 1 is 1,000 rad/hr what will the dose rate be at H + 2?

$$\frac{1,000}{2} = 500 \times 10\% = 50$$

$$500 - 50 = 450 \text{ rad/hr at H + 2}$$

c. The last rule is called the "FIT–forever rule." This rule deals with the dose only. The rule is described by the formula D = F x I x T where:

D = the dose which would be received by an individual who stays <u>forever</u> at a particular location in fallout.

F = 5, a constant for all problems.

I = the intensity or dose rate at that location at the time he reached that location and began his exposure.

T = the time in hours after the burst that he began his exposure.

If a man reached a particular spot in a fallout field at H + 4 and the dose rate was 20 rad/hr, what dose would he receive if he stayed indefinitely?

D = F x I x T

D = 5 x 20 x 4

D = 400 rad total dose

d. So you can see, we do have some ways to calculate or estimate future dose rates and doses due to fallout radiation. Fallout contamination is a hazard, not an obstacle. Like any other hazard we can reduce its effects if we know how to handle it. This information will be valuable to you if you are faced with the problem of working in or moving through a fallout contaminated area.

3–11. RESIDUAL RADIATION PROBLEMS AND SOLUTIONS

a. **Nomograms.**

(1) Given: R1 = 50 rad/hr.

Find: R2.5.

Answer: 16 rad/hr (acceptable range 14–18 rad/hr).

Solution: Use page A–12 in Appendix A, GR 76–332–100. Align the hairline at the 2.5 hour tickmark on the index scale. Pivot about the intersection on the index line (H + 2.5) to the 50–rad/hr point on the R1 scale. Read the DR at H + 2.5 hours where the hairline intersects the Rt scale at 16 rad/hr.

(2) Given: R1 = 80 rad/hr.

Find: The time in hours after the burst when the dose rate decays to 35 rad/hr.

Answer: H + 2 hours (acceptable range H + 1.8 – H + 2.2 hours).

Solution: Use page A–12 of Appendix A, GR 76–332–100. Align hairline at 80 rad/hr on the R1 scale and 35 rad/hr on the Rt scale. Read the time corresponding to Rt on the index scale as H + 2 hours.

(3) Given: R6 = 120 rad/hr.

Find: Dose rate at H + 30 hours.

Answer: 16.5 rad/hr (acceptable range 15 – 18 rad/hr).

Solution: Use page A–12 of Appendix A, GR 76–332–100. Align hairline to intersect the Rt scale at 120 rad/hr and the index scale at 6 hours. Read R1 as 1,000 rad/hr. Rotate hairline to keep hairline at 1,000 rad/hr on the R1 scale and to intersect the index at 30 hours. Read R30 = 19 rad/hr on the RT scale.

(4) Given: a. Entry time = H + 4 hours.

b. Stay time = 4 hours.

c. R1 = 100 rad/hr.

d. No radiation protection

Find: Total dose (D).

Answer: 48 rad (acceptable range 44 – 52 rad).

Solution: Use page A–13 of Appendix A, GR 76–332–100. Lay hairline to intersect H + 4 hours on the entry time (Te) scale and 4 hours on the stay time (Ts) Scale. Note a point at about .495 on the index scale. Rotate the hairline around this point on the index scale to intersect 100 rad/hr on the dose rate (R1) scale. Read total dose as 48 rad on the total dose (D) scale.

(5) Given: a. Entry time = .9 hours.

b. Stay time = 30 minutes (same as .5 hours on nomogram).

c. R1 = 60 rad/hr.

d. No radiation protection.

Find: Total dose from fallout.

Answer: 26 rad (acceptable range 24 – 28 rad).

Solution: Use page A–13 of Appendix A, GR 76–332–100. Procedure same as in 4 above. Rotate on index at about .43.

b. **Rules of Thumb.**

(1) Given: R3 = 200 rad/hr.

Find: R21.

Answer: 20 rad/hr.

Solution: By observation it is apparent that the "7–10" rule applies, 21 being the product of 7 x 3. There is one sevenfold increase in time, hence one tenfold decrease in intensity. Therefore, 200 x 10% = 20 rad/hr.

(2) Given: R3 = 300 rad/hr.

Find: R6.

Answer: 135 rad/hr.

Solution: It is apparent that 6 is twice 3. Therefore, we must use the "double–the–time" rule. 300 E 2 = 150. 10% of 150 is 15. 150 – 15 = 135 rad/hr.

(3) Given: a. Time of entry = H + 2.

b. R2 -= 50 rad/hr.

c. Stay time = infinity.

Find: Total dose, unprotected.

Answer: 500 rad.

Solution: This problem requires use of the "FIT-forever" rule. FIT stands for Five x Intensity x Time of entry, and gives us a total dose for an infinite stay in the area of interest. F (5) is a constant. I, in this case, is 50 rad/hr. T is H + 2. Therefore, 5 x 50 x 2 = 500 rad total dose for an infinite stay.

(4) Problem: At a particular location in a fallout area, the dose rate measured at H + 2 hours was found to be 90 rad/hr.

Requirements: a. Using the "seven-ten" rule, what will the dose rate be at H + 14 hours?

b. Using the "double-the-time" rule, what will the dose rate be at H + 8 hours?

c. Using the "FIT forever" rule, what would be the maximum dose to individuals who moved into this area at H + 2 hours?

Answers: a. $\frac{90 \text{ rad/hr}}{10} = 9 \text{ rad/hr.}$

b. $\frac{90 \text{ rad/hr}}{2} = 45 \text{ rad/hr.}$

45 rad/hr - 4.5 = 40.5 rad/hr.

$\frac{40.5 \text{ rad/hr}}{2} = 20.25 \text{ rad/hr.}$

20.25 rad/hr - 2.025 = 18.2 rad/hr = R8.

c. D = FIT = 5 x 90 x 2 = 900 rad.

Section III. MANAGEMENT OF MASS CASUALTIES

3–12. INTRODUCTION

a. In September 1961, President Kennedy made the statement, "Nuclear weapons and the possibility of nuclear war are facts of life we cannot ignore today." The facts about nuclear warfare are not pleasant, yet they need to be known to dispel some of the confusion, misconceptions, and misunderstandings that exist. If we are afraid to discuss these issues and to face up to the grim facts, we will certainly be afraid to meet the crisis if, and when, it comes. This section covers, in general, the effects of nuclear weapons in a mass casualty situation, benefits of shelter and warning, use of sorting stations and type of treatment, need for training and the training of nonmedical personnel, and stockpiling of equipment.

b. The implementation of these considerations requires an understanding of the following: (1) the effects of nuclear weapons on people and property; (2) the benefits of protection in lessening the medical workload; (3) the exploitation of known and accepted mass casualty care policies to extend the best possible care to a large number of casualties; (4) the training and maximum use of all health workers; (5) the stockpiling of supplies and preplacement of medical facilities; (6) preventive and corrective measures to stabilize environmental health problems; (7) administrative support and control; and (8) an overall regional medical disaster plan that provides the framework within which each of the foregoing measures is accomplished.

c. A mass casualty situation is one in which a sufficiently large number of casualties is generated relatively simultaneously so as to far outweigh our normal treatment capabilities, which are additionally lessened by the loss of medical personnel, goods, and facilities. The appearance of an organized medical effort is likely to be delayed for a period of time and a great disparity will exist between the extent of the problem and the medical means to solve it. This disparity exists in three main areas: (1) the magnitude of the casualty workload, (2) the need for trained personnel to provide care, and (3) the necessity for supplies and facilities to support casualty management.

d. Obvious approaches to overcome this disparity are to: (1) use protection to lessen the casualty load; (2) train personnel in self–care procedures to contain the casualty problem until organized medical help is available; (3) train paramedical personnel and physicians to follow accepted mass casualty care principles of sorting, treatment, evacuation, and hospitalization in order to best cope with the medical workload; and (4) pre–position facilities and stockpile supplies so that medical care personnel have a place to work and something with which to work.

e. Beyond the period of shelter and self–help, a logical approach to organized medical care is to prearrange all the medical facilities around each potential target city into a single regional casualty care system. In the military, regional medical organization is provided as part of an area damage

control plan. Provision is made to support the target zone with nonmedical rescue and delivery, casualty sorting stations which provide sorting and emergency care, and nearby predesignated support-facilities which have altered their configuration to suit mass casualty needs. Additional support is provided in depth on a regional basis by existing, intact hospitals. In civilian communities, the principles of this regional system may be applied by using multiple pre-positioned casualty collecting stations, nearby intact, expanded community hospitals and more distant supporting hospitals each aligned on every main road leading away from the target city and arranged to provide a step-wise chain of sorting, treatment, evacuation, and hospitalization. This system provides the means for putting into practice all the known concepts and programs for mass casualty care and disaster medical planning.

3-13. PROTECTION AGAINST NUCLEAR WEAPONS

Protection against the blast, thermal, and ionizing radiation effects of nuclear weapons is provided by three factors--shielding, distance, and time (SDT). The more shielding put into a shelter, the better the protection afforded. The greater the distance from ground zero the less shelter needed for immediate survival. With the passage of time beyond weapon detonation, all the weapons effects become diminished, leaving one chief hazard--radioactive fallout. It, too, decays at a certain rate, making shelter protection relatively more effective as time passes. Medically speaking, all three shelter factors have the potential of lessening the casualty count. The more widespread that shelter usage becomes, the more manageable is the medical problem. The value of shelter, especially against the fallout hazard, seems unquestioned.

3-14. MOCK THERMONUCLEAR ATTACKS

a. Study by United States Congress Joint Committee on Atomic Energy.

(1) Studies of mock thermonuclear attacks have shown, interestingly enough, that in all probability, radioactive fallout might produce more casualties than the immediate bomb effects. One such unclassified study using 1446 megatons of weapon yield on 224 U.S. cities reveals that there would be about 70 million victims--50 million dying and 20 million left as surviving injured. It was estimated that in the surviving injured group only one-third of the casualties would be caused by the blast and thermal weapon effects while two-thirds would be produced by ionizing radiation from radioactive fallout. If the population had 30 minutes warning and appropriate shelter, then the number killed would be reduced to 14 million and the number of surviving injured reduced, theoretically, almost to zero. There obviously would still be surviving patients in such numbers as to be of grave concern, but the medical workload is reduced and is more manageable.

(2) One way to relate the effect of protection on the casualty workload is to consider some interesting guesswork statistics regarding a theoretical patient-physician ratio. Using figures from the same attack, with an unwarned and unprotected population, there are 10 million patients generated. It is estimated that 75 percent of existing hospitals would be

lost in the same attack, and assuming that 75 percent of our 240,000 physicians are lost also, there would be only 60,000 physicians left to take care of 20 million patients. This represents 333 patients per physician. If the shelter program were 90 percent effective, there would be only nine casualties per physician, assuming that physicians are protected the same as others. Although this latter figure represents a sizeable reduction in the patient–physician disparity, in absolute numbers there are still two million patients requiring care. This is a larger casualty load than ever faced in all medical experience. We must still prepare to manage the casualty workload by mass casualty methods and must rearrange our medical planning and action along these lines. Shelter does not eliminate the medical problem entirely, but only makes it more manageable.

b. **Orlando, Florida.**

(1) Orlando, Florida, is 48 square miles in area and has a population of 162,000. If a weapon is detonated in the air on a clear day over the center of the unwarned and unprotected city, the following approximate medical workload results: 52,000 dead, 45,000 injured, and 65,000 uninjured, plus the loss of about 75 percent of existing hospital beds and medical personnel. If we assume that all 500 physicians in Orlando survive and there are 25 experienced surgeons available to do sorting, then at a rate of 50 casualties sorted per hour per team, sorting alone requires 1 1/2 days. For this reason sorting and emergency treatment must proceed concurrently with the physician confining his activities to sorting and overall supervision, while other health workers provide treatment according to the priorities established for the minimal, immediate, delayed, and expectant groups.

(2) Let us further suppose that all 500 physicians in Orlando survive, work only in the operating room and have all the necessary supporting elements, but continue to perform laparotomies, craniotomies, thoracotomies, etc., according to customary standards. It would then require over six days of uninterrupted work to complete the surgical workload. Adding 1 1/2 days for sorting means that some casualties would receive no surgical care whatsoever for many days, or even a week. Even with unreasonable concessions made, Orlando cannot handle the casualty workload alone, nor can it follow customary standards of care. The casualty problem becomes manageable only when Orlando employs proper sorting techniques, utilizes the mass casualty treatment policies and procedures outlined before, and receives outside medical support. This outside support could be provided in the form of a regional medical disaster plan which brings every possible medical resource of an entire area around Orlando to bear on the casualty workload. The exact pattern in the 45,000 injured is extremely difficult to predict, but a crude guess would be that there would be one–third burns,one-third trauma, and one–third of the cases with both burns and trauma, plus injury from prompt ionizing radiation in various combinations with other injuries. However, for the purposes of early sorting, radiation sickness is not considered, since accurate detection of most cases is not medically feasible at this time.

(3) A look at just one of these gross injury types—burns—illustrates the problem that Orlando faces in providing medical care. About two–thirds of the 45,000 casualties would have burns. Of these 30,000 burned

patients, the approximate distribution by extent of burns is: 5 to 20 percent of body burned—50 percent or 15,000 patients; 20 to 40 percent of body burned—10 percent or 3,000 patients. The patients with burns of less than 20 percent of the body will take care of themselves for the most part. The mortality will not be raised appreciably by this approach. The 10 percent of patients with burns of over 40 percent of the body surface have a high mortality rate even with ideal treatment and will be made as comfortable as possible. Those casualties with 20 to 40 percent body surface burns present a major problem since the mortality is closely related to the efficacy of treatment. Most of these patients will be treated by the exposure method. During initial treatment they have a high priority to receive intravenous fluids and antibiotics. Beyond the first few days, oral fluid and electrolyte replacement should be possible. Ideal treatment for these burn groups would require inordinate amounts of blood, bandages, fluids, and drugs far beyond the medical supply means of Orlando.

(4) Let us suppose Orlando, beyond the sorting period, attempts to treat these 45,000 casualties by customary standards, in which case every casualty receives full resuscitation and necessary definitive surgery within 24 hours. An immediate requirement exists for 30,000 hospital beds. Orlando had less than one-tenth this number originally and now 75 percent of these are gone. If we suppose that the beds do exist, then of the 30,000 hospitalized patients, approximately 20,000 need surgery. Assuming that a surgical team does 10.5 cases per 24 hours, as determined by time studies from the Korean War, then over 1,900 surgical teams are required, plus necessary supporting personnel, equipment, and operating rooms in order to complete the surgical task within one day. The hospitalization and surgical requirements alone preclude the possibility of providing care according to customary standards.

3-15. MEDICAL SORTING

a. **Sorting in Combat Situation.** Sorting (triage) is defined as the procedure by which the sick and wounded are classified as to the type and urgency of the condition presented, so that they can be routed to the installation BEST suited for their care. It is a dynamic, continuous, systematized, yet flexible approach requiring the most mature professional judgment available. Sorting has been used successfully in the past by the military as the only logical means to: (1) initiate the handling of a large number of casualties; (2) ensure a maximum utilization of personnel, supplies, and facilities; (3) assure the least delay possible in evacuation and therapy; (4) restore needed manpower; (5) decrease morbidity and mortality to the lowest degree possible; and (6) give the highest priority for treatment to the seriously wounded.

b. **Sorting in Mass Casualty Situation.** Sorting (triage) in a mass casualty situation is the procedure by which the sick and wounded are classified according to the condition presented, but the highest priority is now given to lifesaving and group effectiveness procedures and the patients are now routed to any medical installation. Now we must give a high priority to those requiring simple lifesaving measures, short definitive surgical procedures that resuscitate, and minor definitive treatment that restores the patient to an effective state. The goals are to save lives and restore group

effectiveness for the maximum number, within the available means. Sorting is not to be interpreted as a method of ascertaining whether or not casualties receive treatment at all. Wherever possible, all patients receive emergency and comfort care. Sorting does determine in what order treatment is given and, moreover, establishes a priority for the definitive care given subsequently.

c. **Person Doing the Sorting.** The person doing the sorting should be an experienced physician, well-versed in trauma and disaster practices. He must not only be professionally competent but also should have knowledge where possible of the total extent of the casualty problem expected, availability of medical support, and many facets of the problem other than patient care. Any of these factors may affect the sorting and treatment techniques employed. The physician should not become involved in the performance of treatment procedures. His experience and judgment are needed to delegate treatment priorities. Other workers, especially paramedical personnel, will provide most of the treatment, so that sorting and treatment may proceed concurrently.

d. **The Sorting Team.** Sorting is performed at every facility handling patients. However, initial sorting is performed adjacent to the disaster site by a sorting and emergency care team. In the military, a typical sorting team consists of a physician in charge, a dental officer as his assistant in charge of treatment, and between 12 and 15 medical specialists who provide emergency care. This team is dispatched from the nearest medical facility to the disaster area. Its mission is to provide early care for the injured according to the priorities outlined in paragraph e below, return the minimally injured to gainful work after treatment, and to evacuate those patients needing hospitalization. This team cannot become involved in the rescue and delivery of the injured to the sorting station. Nonmedical workers must accomplish this job, which again emphasizes the importance of teaching laymen proper methods for transporting patients. Sorting is continued at the receiving medical facility, but it now assumes a different aspect since many patients have been removed from the medical system by death or return to work. Priorities are now established for the order in which definitive care is given. The extent of the definitive procedure provided is determined by the mass casualty treatment policy for that facility.

e. **Categories of Sorting.** For purposes of classifying patients to be sorted in mass casualty situations, the military services have adopted four categories, as described below. The American Medical Association classifications (priorities) are in parentheses. A rough estimate of the percentage of the total injured to be expected in each category is also shown.

(1) Minimal category (priority I) 40 percent. Patients who may be returned to duty qualify for minimum treatment and include those who have small lacerations or contusions; closed fractures of small bones; or second-degree burns of less than 20 percent of the body but not involving incapacitating burns of face, hands, or feet.

(2) Immediate category (priority II) 20 percent. Included as patients requiring immediate care are those with hemorrhage from an easily accessible site; rapidly correctible mechanical defects; severe crushing

wounds of the extremities and incomplete amputations; and open fractures of major bones. The patients in this group will be given the highest priority for surgical treatment because a relatively short procedure could save life or limb. More definitive surgery would be delayed to a later date. An increased rate of complications and permanent disability would have to be accepted.

(3) Delayed category (priority III)—20 percent. Persons whose surgical treatment can be delayed without immediate jeopardy to life include those with simple closed fractures of major bones; moderate lacerations without extensive bleeding; second-degree burns of 20 to 40 percent of the body surface; and noncritical central nervous system injuries. This group is composed of patients for whom a delay in treatment might lead to complications but whose lives would not be unduly jeopardized by delay. The amount of delay between wounding and surgery for this group depends on the total number of patients with higher priorities who need treatment and the medical facilities available.

(4) Expectant category (priority IV)—20 percent. Included in this category are patients whose treatment would be on an extended delayed basis. The patients include those with critical injuries of the central nervous system or respiratory system; penetrating abdominal wounds; severe multiple injuries; and severe burns of over 40 percent of the body surface. The treatment of this group of patients would consist of that resuscitation and emergency medical treatment which the available facilities, total supplies, and number of professional personnel permit. They would have the lowest priority for surgery because the operative procedures required would be time consuming and technically complicated, so that an operation on one of these patients would theoretically jeopardize the lives of several in other higher priority groups. The more rapidly patients in other treatment categories are moved, the sooner more definitive treatment could be started on the injured in this category.

3-16. PHASES OF CASUALTY CARE

a. For medical planning purposes, the time period after an attack is arranged into four phases: (1) Phase I (up to 3 days)—the period before organized medical help is available. Self-care and first aid constitute the bulk of casualty care; (2) Phase II (3 to 20 days)—casualty care is provided chiefly by paramedical workers under the supervision of physicians according to an organized plan; (3) Phase III (20 to 60 days)—treatment principles will follow more customary lines except for considerations due to the size of the remaining casualty load. Presumably, there is little resupply of resources. The last is Phase IV (after 60 days)—resupply begins and essentially normal medical practice resumes. These phases are purely arbitrary insofar as the time division is concerned. Separate phases may exist concurrently or be prolonged by lack of personnel or equipment. Although predicted only upon a single attack, the concept is useful for medical planning. Of prime concern is the casualty care and medical supply occurring in phases I and II, the period of greatest mass casualty emphasis.

b. As recommended by the American Medical Association Commission, paramedical workers should be trained to perform certain patient care func-

tions, especially those of a lifesaving nature, ordinarily reserved for physicians in order to relieve the physician of duties that others can perform and to ensure the maximum possible use of all health resources. Patient care functions for this group are shown in Table 3–3.

c. During phase II, nurses, veterinarians, dentists, and many other allied health workers will play an important role in providing organized medical help according to plan. These workers must have prior training, legal permission, and proper supervision in order to do their best job. Patient care functions for this group are also shown in Table 3–3.

3–17. EMERGENCY MEDICAL CARE

a. The ability of lay citizens or soldiers to protect themselves, bind up their own wounds, care for families and friends, and deliver casualties to treatment facilities, largely determines the casualty workload faced later by organized medical support. The American Medical Association Commission recommended that "the general public receive training and become proficient in the application of first aid and self–aid procedures." Such training is now available in the medical self–help training programs for civilian laymen, the Air Force Buddy–Care Program under AF Pamphlet 160–2, and the Army's Training in First Aid, FM 21-11, 7 October 1985.

b. Although the above programs are not identical in scope, content, and teaching method, all have the same purpose. The goal of the Army program is to teach the essentials of self–aid and emergency medical care to every soldier and officer not in the Army Medical Department. The following proficiencies are included.

(1) Stop bleeding—pressure dressing, tourniquet as a last resort.

(2) Airway management—initial measures, mouth–to–mouth resuscitation.

(3) Wound care—sterile and improvised dressings.

(4) Prevent and treat shock.

(5) Splinting fractures.

(6) Emergency care of burns, head wounds, chemical injuries, etc.

(7) Psychological first aid.

(8) Transportation of wounded.

c. Additionally, nurses, veterinarians, and dentists should know how to give simple anesthesia, and the dentists will sort and care for facial injuries. For the other disciplines, the list of functions is modified according to the medical skill level and past experience of that particular group. For example, enlisted personnel without patient care experience are required only to have the nonmedical proficiencies, plus training in basic

nursing (blood pressure, temperature, pulse, and respiration) and psychological care.

3–18. SUMMARY

"Business as usual" ceases quickly in a disaster. The use of normal standards of medical care will only increase the early casualty problem. The medical and allied health services must provide the best service possible for the greatest number, according to standards of care acceptable to the situation, and utilize all resources to the maximum. Teamwork is the key to success—teamwork established through planning and practice prior to disaster.

	MC	DC	VC	AN	MS	SP[1]	SP[2]	WO[3]	WO[4]	WO[5]	EM[6]	EM[7]
1. Concept of medical sorting (triage).....	X	X	X	X	X	X	X	X	X	X	X	X
2. Burns.....	X	X	X	X	–	X	–	X	–	X	X	–
3. Blood collection.....	X	X	X	X	–	–	–	X	–	–	X	–
4. Parenteral fluid therapy.....	X	X	X	X	–	–	–	X	–	–	X	–
5. Care of maxillofacial injuries.....	X	X	X	X	–	–	–	X	–	–	X	–
6. Assisting in major surgery.....	X	X	X	X	–	–	–	X	–	–	X	–
7. Duties of scrub and circulating nurse...	X	–	–	X	–	–	–	X	–	–	X	–
8. Preoperative and postoperative care.....	X	X	X	X	–	–		X	–	–	X	–
9. Use of tubes.....	X	X	X	X	–	–	–	X	–	–	X	–
10. Preparation of sterile supplies.....	X	X	X	X	X	–	–	X	–	–	X	–
11. Blood pressure, temperature, pulse, and respiration.....	X	X	X	X	X	X	–	X	–	X	X	X
12. Urinary bladder catheterization— administration of enemas.....	X	–	–	X	–	–	–	X	–	–	X	–
13. Major aspects of psychological care.....	X	X	X	X	X	X	X	X	X	X	X	X
14. Establishment of an emergency airway....	X	X	X	X	X	X	–	X	–	X	X	–
15. Suturing technique.....	X	X	X	X	–	–	–	X	–	–	X	–

Footnotes:
1 Less dietitians
2 Dietitians only
3 Physician Assistant
4 Medical equipment repair technician
5 Aviator
6 Patient care MOS
7 Other than patient care MOS

Table 3-3. Emergency medical treatment procedures.

EXERCISES, LESSON 3

REQUIREMENT. The following exercises are to be answered by marking the lettered response that best answers the questions; or by completing the incomplete statement; or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson, and check your answers with the Academy solutions.

1. A low airburst of a 1 KT nuclear weapon has severely damaged a nearby frame house. What is the approximate number of pounds per square inch (psi) exerted at the house?

a. Less than 1.

b. A little less than 2.

c. A little more than 2.

d. About 3.

2. In problem 1 above, you estimate the radius of damage to be about_____meters.

a. 725.

b. 600.

c. 575.

d. 300.

3. A 10 KT weapon has been detonated at a distance of 1100 meters from your protected position. From information you have received it appears to have been a surface burst. What results do you expect to find when it has been determined that it is safe for personnel to emerge from the protected position? Severe damage to:

a. Parked aircraft.

b. Oil storage tanks.

c. Bunkers and underground structures.

d. All of the above.

4. You have experienced second degree burns on your face and hands in a low air nuclear detonation which had a ground zero about 805 meters away from your exposed position. You estimate the yield of the weapon to be about _____ _____KT.

a. 0.1.

b. 0.5.

c. 1.

d. 5.

5. If you are in a foxhole 1260 meters from ground zero of a nuclear detonation and the foxhole collapses, what would likely have been the yield of the weapon?

a. 1 KT.

b. 10 KT.

c. 100 KT.

d. 10 MT.

6. Nausea and vomiting will likely occur within one hour in personnel who are within 580 meters or less from the airburst detonation of a 1 KT nuclear weapon. If another person has suffered these same effects in another nuclear explosion, at a distance of 1300 meters, what would likely be the yield of the second weapon?

a. 1–0 KT.

b. 100 KT.

c. 1 MT.

d. 10 MT.

7. You have been asked to estimate the degree of thermal injury to the bare skin, produced by a 5 KT nuclear weapon (airburst), with a ground zero of 1500 meters from your unit. You say it:

a. Is third degree.

b. Is second degree.

c. Is first degree.

d. Does not produce any thermal injury.

8. If the burst in Exercise 7 had been a surface burst, the calories per centimeter squared (cal/cm2) would have been:

a. 8.

b. 6.

c. 3.2.

d. 1.5.

9. Which of the following personnel should perform medical sorting?

a. Any medical or paramedical personnel.

b. Only paramedical personnel.

c. Medical Corps officers of mature professional judgment.

d. Medical officers, dental officers, and nurses.

10. What would be the logical approach to organized medical care of mass casualties for civilian communities?

a. Prearrange all medical facilities around each potential target into a single regional casualty care system.

b. Augment the military Area Damage Control Plan and rely on it in the case of mass casualties.

c. Depend entirely upon the nearest military installation for organized medical care of the injured.

11. Following the burst of a nuclear weapon, which of the following casualty types would you expect to find in the <u>immediate treatment</u> category?

a. Closed fractures of major bones.

b. Noncritical burns over 20–40 percent of the body.

c. Critical injuries to the central nervous system.

d. Open fractures of major bones.

12. In a mass casualty situation, about what percent of all casualties is expected to need only minimal treatment?

a. 80.

b. 40.

c. 20.

d. 10.

13. In a mass casualty situation, which of the following categories would have the lowest priority for surgery?

a. Immediate.

b. Expectant.

c. Delayed.

d. Minimal.

14. The time period after a nuclear attack is divided into four phases for medical planning purposes. What kind of help would you expect in phase II?

a. None.

b. Self-care and first aid.

c. Paramedical workers under the supervision of physicians.

d. Essentially normal medical practice.

15. In the event of a nuclear detonation, trained medical personnel would be used in all of the following, EXCEPT_____.

a. Medical sorting.

b. First aid.

c. Rescue operations.

d. Treatment facilities.

e. a and c above.

f. b and c above.

16. List the three methods that can be used to calculate dose rates and total doses.

_____

_____

_____

17. If the dose rate at H + 1 is 500 rad/hr, what will be the dose rate at H + 2?

a. 225.

b. 200.

c. 150.

d. 75.

18. The most accurate method for calculating dose rates and total doses is the_____.

SOLUTIONS TO EXERCISES, LESSON 3

1. d (Appendix A, page A–40)

2. a (Appendix A, page A–40)

3. a (Appendix A, page A–39)

4. c (Appendix A, page A–41)

5. c (Appendix A, page A–39 or A–40)

6. b (Appendix A, page A–42)

7. b (Appendix A, page A–41)

8. d (Appendix A, page A–41)

9. c (para 3–15c)

10. a (para 3–12e)

11. d (para 3–15e(2))

12. b (para 3–15e(1))

13. b (para 3–15e(4))

14. c (para 3–16a)

15. f (para 3–15d)

16. Nomograms; ABC–M1 RADIAC Calculator; rules of thumb. (para 3–7)

17. a (Appendix A, page A–12)

18. Nomograms (para 3–7)

LESSON ASSIGNMENT SHEET

LESSON 4	--Command Guidance on Irradiated Personnel and Nuclear Accidents and Incidents.
LESSON ASSIGNMENT	--Paragraphs 4–1—4–12.
MATERIALS REQUIRED	--None.
LESSON OBJECTIVES	After completing this lesson, you should be able to:

4–1. Identify various factors influencing incapacitation following exposure to radiation under combat conditions.

4–2. Be able to provide an estimate of probable effects of certain radiation exposures to his troops in terms of gross physical effectiveness.

4–3. List the hazards of a nuclear accident and necessary precautions.

4–4. Describe current concepts of medical operations in a fallout to specific situations.

SUGGESTION --After completing the lesson assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 4

COMMAND GUIDANCE ON IRRADIATED PERSONNEL AND
NUCLEAR ACCIDENTS AND INCIDENTS

Section I. COMMAND GUIDANCE ON IRRADIATED PERSONNEL

4–1. INTRODUCTION

The characteristic of nuclear weapons which is of greatest concern to the Army Medical Department is their tremendous capability for the production of casualties. We devote a great deal of time and effort to the handling of mass casualties. We also know that the Army Medical Department must be prepared to continue medical operations in support of both nuclear and conventional casualties despite the tremendous potential of nuclear weapons to damage and destroy everything from facilities to communications. These are tremendous challenges, and in our concern for these problems, we usually overlook another nuclear medical responsibility which is peculiarly military and is absolutely vital to the Army's combat support mission. This is our time–honored responsibility for advising the commander upon all matters pertaining to the health of the command. Ionizing radiation is of interest to a commander for one reason: because of its effect upon people. Commanders at every level look to their surgeons for advice on the effect of radiation exposure upon troops. To make proper decisions, a commander needs information on both the present and future health of his command. On the battlefield, health is affected by trauma and disease. Radiation sickness is a disease. The effect on present health of a command of a particular disease is merely a tabulation of the daily reports of subordinate units. To predict the effect of a given disease on the future health of a command requires a reliable military experience factor. There is no such factor for radiation sickness. Therefore, to comment intelligently and reliably, the staff surgeon must familiarize himself with the present state of our knowledge and examine the parameters, which influence his advice. But at this point we need to define some terms.

4–2. DEFINITIONS

a. **Command Radiation Guidance.** Advice of the staff surgeon on the effect and influence of predicted and actual radiation received by a command.

b. **Operational Exposure Guidance (OEG).** The maximum amount of nuclear radiation which the commander considers his unit may be permitted to receive while performing a particular mission or missions. The numerical value for this guide is established by battalion and higher levels only, and is based upon the unit radiation status and degree of risk criteria.

c. **Acute Dose.** The total dose accumulated in 24 hours.

d. **Protracted or Fractionated Dose.** Total accumulated in time periods greater than 24 hours when delivered in increments.

e. **Reference Dose.** The amount of penetrating whole body radiation which is related to certain early effects of radiation on personnel. Dose–effects relationships.

4–3. EFFECTIVENESS

a. **Individual.** A key word in a discussion of command radiation guidance is the word "effectiveness." An effective individual is, of course, one who is capable of carrying out an assigned task. Therefore, to be meaningful, effectiveness must be described in terms of the task to be performed. Generally, combat effectiveness has been described in terms of gross physical effectiveness, requirements for which might vary from over 90 percent effectiveness required to carry on hand–to–hand combat to as little as 10 percent effectiveness required to simply fire a weapon. Most studies and discussions of the relationship between radiation exposure and military effectiveness have been based primarily upon gross physical effectiveness. It should be obvious, however, that there are military tasks requiring other kinds of effectiveness: manual dexterity, high skill levels, judgment, decision making, etc. The effect of radiation upon this kind of effectiveness is not well understood, but it is the target of much intensive research today. Table 4–1 illustrates this relationship between radiation exposure and physical effectiveness.

(1) Fire a preplaced weapon	10%
(2) Operate radio communications	20%
(3) Drive a vehicle	50%
(4) Aim a weapon	80%
(5) Assault a position	90%
(6) Hand–to–hand combat	90+%

Table 4–1. Physical effectiveness required to perform typical combat tasks.

b. **Unit Effectiveness.** Military commanders are more interested in unit effectiveness than in individual effectiveness. A commander wants to know, for example, what will happen to a certain unit if new radiation exposures are received, or what will happen to another unit as a result of an acute radiation exposure just received. How many individuals must be noneffective in order to make a military unit noneffective? Certainly if 50

percent of a unit is noneffective, the unit is noneffective. It is generally agreed that if one-third of a unit is incapacitated, the unit is non-effective. Who is noneffective in the unit might be as important as the mere percentage of noneffectives. For example, loss of the command element might render a combat unit ineffective, or loss of the surgeons in a surgical hospital makes the hospital noneffective as a surgical hospital.

4-4. RADIATION DOSES RESULTING IN NONEFFECTIVENESS

a. **General.** The command surgeon must try to tell his commander not only if his troops will be incapacitated, but, insofar as possible, when. The timing of ineffectiveness is particularly important to the commander. He must consider time in two ways: first, the time-phasing of the radiation exposure, and second, the course of the radiation illness. First, consider the timing of the exposure: was it an acute or prolonged exposure?

b. **Acute Doses.**

(1) Most dose-effects are for acute exposures, simply because more valid and reliable reference dose information is available for acute exposures. If we look at the dose-effects relationships for moderate acute exposures, we can see that the time-phasing of the incapacitation which results is important to the military commander. Those exposed even to lethal doses of a few thousand rad and below do not become ineffective at once, nor do they necessarily remain ineffective once they have lost effectiveness. In the hematopoietic form of the disease, first there is a delay in the onset of symptoms following the exposure. This delay period may be one of days, or it may last only a few minutes, depending largely upon the magnitude of the dose. After the delay period, there is a prodromal phase lasting 2-3 days. This is followed by a latent period of perhaps 2-3 weeks. The latent period may be much shorter for high doses, on the order of a thousand rad or more. On the other hand, for very low doses, the prodromal phase may be so mild that effectiveness continues right on through it. The final phase is the bone marrow depression phase, with onset about the third week after exposure. This phase is terminated in several months by death or recovery. Note the two periods of some degree of effectiveness in the above discussion. There is the delayed onset period of minutes to days, and the latent period of from nothing to 2 to 3 weeks. These periods are of considerable importance to the commander and to the surgeon who advises him.

(2) If we look at very high acute exposures, those in the CNS range, we see yet another time-effectiveness picture. We must realize that, while we talk of the hematopoietic form of radiation sickness occurring following exposures from 200 to 800 rad, the gastrointestinal form from 800-3000 rad, and the central nervous system form from 3000 rad, in reality there is no sharp line of demarkation between these various forms of the sickness.

(3) In any case, the time-effectiveness picture following exposures at these levels differs considerably from that which has been presented for more moderate acute exposures. For this reason, the biological effects of this type of exposure are probably receiving more attention right

now than any other type of radiation effect. A review of those studies conducted to date leads to the following conclusions:

(a) Even at doses over 2,500 rad, survival is possible for several days with considerable effectiveness for much of the survival time.

(b) Although there is wide variation between individuals, the higher the dose, the earlier the irreversible incapacitation.

(c) Very high doses of radiation are required for incapacitation in minutes—doses on the order of 80,000 rad.

(d) There is evidence of a phenomenon called early transient incapacitation (ETI). This incapacitation occurs 5–7 minutes after exposure and lasts 8–10 minutes. The degree of ETI depends upon the magnitude of the dose.

(e) Vomiting occurs only in some of those exposed at this level. It is interesting and important to note that these studies demonstrate clearly, when vomiting does occur, that it, of itself, is not necessarily incapacitating.

(4) Now let us look at several examples of the interrelationship between the surgeon's advice and the commander's decision in several tactical situations involving acute radiation exposures to troops.

(a) In the first situation, troops are in a defensive position of underground bunkers and machine-gun positions. The tactical nuclear weapon is a low airburst whose GZ is several hundred feet from the defensive position. The troops have excellent protection against thermal and blast effects, but still receive a mixed gamma and neutron dose of about 20,000 rad. Given a good estimation of the dose to troops, the surgeon can tell the commander that some troops will be ineffective in 5–10 minutes. Fifty percent of them will be ineffective at the end of the first hour after exposure. All of these troops will die within a time period from a few hours to a day or so following exposure, whether or not they receive medical treatment. Whether the military situation is routine or emergency, there is really no decision for the commander. The surgeon can tell him that the unit is gone. The commander will have to replace the unit as soon as possible probably from his reserves. From the surgeon's standpoint, there is really no medical decision to be made, either. Medical evacuation and treatment will probably have no effect upon the course of the sickness and no effect upon the eventual outcome. From the commander's point of view, the early realization that this unit has been eliminated is valuable information and his prompt action may well affect the outcome of the battle.

(b) In a second tactical situation, the same troops in the same defensive situation are exposed to a tactical nuclear weapon burst with GZ several hundred meters away. In this case, blast and thermal effects are essentially nil, but troops receive an acute dose of initial radiation on the order of 800 rad. In this case the surgeon can tell the commander that all will eventually die, but most could fire their weapons for several hours; many

could fire for a day; some could fire for several days. Here the commander's decision depends upon whether this is a routine or emergency situation. A realization that a substantial portion of the forces can continue the defense for some hours and perhaps for a day or so, may be extremely important in an emergency situation. It is also important to the commander to know that prompt medical evacuation and treatment will probably not save any of these exposed personnel. In an emergency, the commander may have to order these troops to continue the defense. On the other hand, of course, if the military situation is not critical, those exposed should be medically evacuated as symptoms appear.

(c) In the third tactical situation, troops are in foxholes, trenches, and tanks hundreds of meters from GZ. Troops are not affected by blast and thermal effects, but receive doses of radiation between 300 to 400 rad. The surgeon tells the commander that some of these troops will become noneffective within 24 hours, while some may be able to continue fighting for a week or more. All would benefit from medical evacuation within 24 hours. All, or nearly all, should recover with treatment, but those who continue fighting for more than a couple of hours will have a much poorer chance for survival. With treatment, all should return to duty in two months or so. The commander's decision here again depends upon whether the military situation is routine or emergency. If it is routine and the unit is not under pressure or attack, personnel should be evacuated as symptoms appear and evacuees should be replaced. In an emergency situation, troops can continue to fight, especially in a defensive action for several days. But the resulting stress and delay in treatment will certainly kill a substantial percentage of the irradiated troops.

(5) To illustrate this last point, there is the historical example of a Japanese Army battalion at Hiroshima which is alleged to have received a dose of 300 rad when the Hiroshima bomb detonated. The military commander believed the attack to be a part of a pre-invasion softening-up, so he implemented his portion of an emergency defense plan. He ordered the battalion to make a forced march to defensive positions some 35 miles away. All of the troops in this battalion died within 60 days. With a dose of 300 rad, all should have survived. It is important from a commander's viewpoint, however, to point out that if this had been a part of an invasion, that battalion, after reaching defensive positions, would have been able to carry on defensive combat for several days despite the fact that all were eventually to die.

c. **Prolonged Exposure.** The prediction of effectiveness subsequent to acute radiation exposure is difficult at best, but it is simple when compared with the prediction of effectiveness resulting from prolonged or fractionated radiation exposures. Yet the prolonged exposures may be the most likely kind making the greatest demand upon the surgeon for advice to the commander. There are several reasons why this type of exposure is most likely for survivors of nuclear attacks.

(1) Factors limiting number of survivors.

(a) First, there are a number of factors which tend to limit the number of personnel with significant radiation exposures who survive nuclear attack. The nature of the initial radiation pattern surrounding a low air burst tactical weapon is such that doses are very high close-in to GZ. However, doses drop off very rapidly within a short distance at some radius from the GZ. For this reason, most exposed personnel will sustain either a very high lethal dose or a militarily insignificant dose of initial radiation. Only personnel within a very narrow ring or "doughnut" around ground zero will survive with a dose which still requires continuing concern for future effectiveness.

(b) Another factor limiting the survival of those with significant acute radiation exposures is the fact that, for weapons larger than the tactical-sized weapons, blast and thermal effects tend to overwhelm radiation. Thus, personnel receiving significant but not lethal radiation exposures are likely to be killed by something other than radiation.

(2) Factors tending to increase survivors. At the same time, there are some factors which tend to increase the number of military personnel receiving significant but nonlethal doses as prolonged radiation exposures. Most of these are related to local radiological fallout. Radiation is the only hazard in fallout. There is no associated heat or blast effect to kill those exposed. The area involved in fallout radiation is many times the area involved with initial radiation. It is likely that the serious fallout area will be 100 times as large as the initial radiation area from the same weapon. Therefore, many more troops could be expected to be involved with the fallout radiation. Finally, the radiation hazard of initial radiation lasts for only a minute, but that of local fallout continues for days, allowing a much greater period of time for individuals to encounter the radioactive area and sustain injury.

d. **Lack of Reference Dose Information for Prolonged Exposure.** A serious handicap to the provision of guidance to the commander concerning these prolonged exposures is the lack of valid reference dose information upon which to base the advice. There are several reasons for this lack. Most human data comes from radiation accidents. Acute exposure accidents are conceivable and do occur, but it is difficult to see how an accident resulting in continuing and prolonged exposure could occur with all the controls and safeguards which govern all activities involving radiation today. It has been suggested that human exposures in radiation therapy might provide useful human effects data; however, those receiving radiation therapy are not well to begin with and the physiological results are usually questionable. Also, therapeutical exposures are usually partial body exposures and effects are quite different from those from whole body exposures. Animal research in the prolonged exposure area is not widespread. The Navy Radiological Defense Laboratory at San Francisco, which was recently closed, was doing more of this type of research than any other research facility. With this source of information gone, there is little to encourage others to work in the area. This type of study is expensive, time-consuming, and is not popular with researchers.

e. **Recovery from Radiation Injury.**

(1) The ability of the human body to recover from radiation injury is obviously closely related to the effects of prolonged radiation exposures, and we are seriously deficient in what we know about recovery from radiation injury. A few years ago we could give precise answers to questions concerning radiation recovery, but we can no longer do so with any assurance. Paradoxically, the reason for our current inability to answer questions concerning recovery from radiation injury is that we know more about it than we did a few years ago. We no longer consider recovery from radiation injury to be exponential, nor does it seem to follow any simple mathematical course, so we have had to give up our practice of quantifying radiation recovery with time.

(2) If we are to make some generalizations with respect to recovery from radiation injury, we can only say that recovery does take place with time, but the rate and degree of recovery at an early time after exposure is not known. We know that some residual radiation injury remains after maximum recovery has taken place. This tends to leave the individual at least slightly more vulnerable to future radiation exposures, but we don't really know how much more vulnerable. Generally, we no longer make any attempt to quantify recovery but simply consider it as a bonus until many weeks have passed after the exposure.

(3) As a result of our lack of reference dose information for prolonged radiation exposures and our very limited knowledge of recovery from radiation injury, we can give the commander only a little general advice concerning these exposures. We can tell him that unit ineffectiveness can be avoided by spreading radiation exposures across longer time periods and among different groups of people, and we can tell him that giving a unit a week or two of rest from radiation exposure may prevent its loss. More specific guidance concerning prolonged radiation exposures is a more complex problem with which the surgeon must deal.

(4) It should be noted that when we speak of resting a unit from radiation exposure, we do not refer to removing the unit from combat and sending it to a rear-area rest camp. A unit can be subject to radiation exposure in rear areas as well as forward areas. A unit can be radiologically rested by locating it in or near excellent radiation shelter and by not committing it to missions involving possible radiation exposure for some period of time.

4-5. TASKS INVOLVED IN THE DEVELOPMENT OF RADIATION GUIDANCE

a. **General.** Regardless of the state of our knowledge of the effects of ionizing radiation upon humans, there are several tasks which we must be able to accomplish if we are to give a commander meaningful radiation guidance. In order to develop radiological guidance, we must be able to:

(1) Determine the radiological status of the unit at a given time.

(2) Measure or predict with accuracy any new exposure to the unit.

(3) Assess the effect of the new exposure on the unit.

b. **Problems Inherent in Accomplishing the Three Tasks.** There are problems inherent in the accomplishment of each of these tasks.

(1) In the first case, what we are trying to do is determine the radiological vulnerability of the unit, or its susceptibility to any new radiation exposure. In this respect we are seriously limited because of lack of valid information on reference doses for prolonged exposures. We are even more handicapped when considering the effect of mixed acute and prolonged exposures. The reference dose information we do have relates to whole body exposures. The fact that most field military exposures are likely to be partial body exposures of varying degrees of complexity further complicates our task. If we are to determine the exposure status of a unit at any given time, we must keep some sort of record of unit radiation exposure. Who should do this and how? There is an official Army system for keeping such exposure histories, but at best such a system is limited in validity by the fact that unit exposures are taken as the average of only two instrument readings. This average can vary considerably from the actual unit exposure experience.

(2) If we are to accomplish the second task in development of command guidance, we must be able to predict or measure new radiation exposures. In predicting new exposures we are on very firm ground when dealing with exposures in completed local fallout fields. These exposures can be both predicted and measured with considerable accuracy. If exposures come through new fallout fields, not completed at the time of prediction, or through acute exposures to new detonations yet to be encountered, then we can make no valid prediction at all. If we are to measure new exposures, we are on firm ground with one exception; we cannot, with radiac equipment currently available, measure the neutron component of initial radiation. Since this is a substantial portion of the dose, we cannot, in effect, measure initial radiation exposures at all. In short, we can accomplish the second task when dealing with fallout, but not with acute exposures to initial radiation. In the latter case, we can only make rough estimates.

(3) The third task requires that we be able to assess the effect of the new radiation exposure superimposed upon the prior unit radiological vulnerability. To accomplish this task, we must be able to do the first two tasks well. As we have seen, there are some limitations in our ability to accomplish the first two tasks effectively. We are further limited in our assessment of the result by our lack of prolonged exposure reference dose information. This puts us in the difficult position of being able to measure and predict fallout exposures with considerable accuracy but not being able to determine the meaning of those exposures in terms of unit effectiveness. It can be seen from this discussion, that in many instances, the development of command guidance for troops exposed to radiation is certainly not an exact

science. Nevertheless, given a few assumptions, the surgeon can offer the commander advice in broad general terms in most instances and some rather precise advice in certain situations. This is shown in Table 4–2.

ACUTE DOSE	PROBABLE EFFECTS
100 rad or less in 24 hours	No ineffectiveness. (No previous radiation.)
100-200 rad in less than 24 hours	Spectrum of response from 0 to temporary illness assuming no previous radiation. No evacuation for temporary illness.
Greater than 300 rad delivered in less than an hour	90 percent vomiting in 6 hours. (If no vomiting within 6 hours, probably under 300 rad.)
500-1000 rad in 24 hours	50 percent require medical evacuation in less than 24 hours. All in medical channels after 24 hours.
REPEATED DOSES	PROBABLE EFFECTS
25 rad in less than 24 hours at weekly intervals for 8 weeks	No ineffectiveness.
350-450 rad gradually over 1 year	Decreased radiation reserve. Decreased efficiency and increased susceptibility to trauma and late effects.

Table 4-2. Acute dose.

Radiation Status Category	Cumulative Dose Received (RADs)	Allowable Single Mission Dose For Each Assigned Degree of Risk (RADs)
RS–0	0	Negligible: 50 Moderate: 70 Emergency: 150
RS–1	0–70 Avg. 40 rad	Negligible: 10 = (50 – 40) Moderate: 30 = (70 – 40) Emergency: 110 = (150 – 40)
RS–2	70–150 Avg. 110 rad	Negligible: N/A (50 – 110 = –60) Moderate: N/A (70 – 110 = –40) Emergency: 40 (150 – 110 = 40)
RS–3	> 150	Negligible: N/A (50 – 150 = –100) Moderate: N/A (70 – 150 = –80) Emergency: N/A (150 – 150 = 0)

Table 4–3. Operations exposure guide.

4–6. THE USE OF NUMBERS IN RADIATION GUIDANCE

a. **The Official System.** There is an official system for recording the radiological exposure status of military units. In brief, the system provides for three radiation status categories to describe the radiation exposure status of all military units up to battalion size. These categories are: Radiation Status RS–1 for those units with militarily negligible doses. This negligible dose is defined as 70 rad. RS–2 units have a dose of 70–150 rad, a significant but not yet dangerous dose. RS–3 units have exposures in excess of 150 rad. These units are shown in Table 4–3. Any further exposure would be considered dangerous for an RS–3 unit. The system also assigns "degrees of risk" to be associated with any new radiation exposure for military units in the various RES categories. One weakness in the system is seen in the fact that it includes no reference to how the exposure was accumulated. For instance: two units might both be in an RS–3 category with a 150–rad exposure, although one unit collected that dose over a period of three weeks, while another got all 150 rad in an acute dose yesterday. Obviously, the first unit is in pretty good shape, while the latter unit is in a precarious

position so far as new radiation exposures are concerned. The system operates in this way: Platoons record radiation exposure in 10 rad increments and report daily to company. Company reports to battalion headquarters. Battalion keeps records by platoon and company and reports battalion status to division headquarters through brigade. There are at least two "safety factors" built into the system. The exposure categories are "safe-sided." Incapacitation thresholds are probably considerably higher than the limitations used in the system, especially when prolonged exposures are considered. There is also no allowance for recovery from radiation injury. It is simply considered as a bonus, and there is no doubt that it is a rather large bonus when dealing with acute exposures several weeks old or prolonged exposures delivered over periods of several weeks. **NOTE: RS and RES can be used interchangeability through out the subcourse.**

b. **The Surgeon's Role.** Once a unit has been assigned an RES category of 2 or 3 can it ever be returned to a lesser radiation exposure status? Yes, it can. This is a decision for the commander to make, although he must lean heavily upon advice from his surgeon in making the decision. The surgeon will offer suggestions for lowering RES categories based upon his knowledge of radiation effects, his evaluation of the overall state of health of the unit, and his experience, when and if he gets it.

c. **Operation Exposure Guides (OEG'S).**

(1) This radiation exposure status recording system is intended to assist the commander and surgeon in the development of operation exposure guides. If you recall the definition of an operation exposure guide (OEG), this is the maximum amount of radiation which a commander will permit his units to receive during a certain period of time or in accomplishing a particular mission. OEG's have their place in conveying radiation exposure guidance from the commander to subordinate units, but they never relieve the commander or his surgeon from the necessity of making decisions concerning radiation exposure. OEG's are more meaningful when applied to small units than to large ones, and more meaningful when dealing with completed fallout fields than when either fallout in progress or initial radiation is encountered.

(2) OEG's are also more practical when applied to units such as combat units, which normally move about in the accomplishment of their missions. They are less practical when applied to those units which must establish a fixed, relatively immobile installation to accomplish a mission. For example, a surgical hospital full of patients is not mobile. It would be an exceedingly rare fallout situation which would allow the commander of such a hospital to evacuate staff and patients to a clear location without serious radiation exposure to both groups in the process. This leaves the hospital commander with only passive defense measures and judicious utilization of radiation shelter to influence the dose to his staff and patients. He can only minimize exposure with or without reference to any established OEG. If an OEG were established at 25 rad and the hospital commander found that, after shelter was achieved, the average dose to the unit rose to 30, 35, or 5-0 rad, he still would have no choice but to continue as he is until some future time. In such a case, the establishment of an OEG has had absolutely

no effect upon the decisions of the commander and might as well not exist so far as that particular commander is concerned.

4–7. COMMAND GUIDANCE RADIATION

In developing radiation exposure guidance for the commander, the surgeon is severely handicapped in some respects, yet the provision of such guidance is essential. In many situations, the guidance cannot be specific, but must be given in general terms unless the commander is willing to make some rather arbitrary assumptions in order to provide the surgeon with a specific situation. It is certain, however, that radiation guidance cannot be given in the form of a few universally applicable numbers, as some surgeons and commanders would hope. Instead, radiation guidance must be custom-tailored to the situation at hand. The surgeon must remember also, as the commander does, that the radiological situation is not itself a determining factor, but must be considered together with all the other factors which the commander must evaluate in making his decision. It is incumbent upon a military commander in nuclear warfare to keep radiation exposure to a minimum commensurate with the accomplishment of his mission. He must depend upon his surgeon for advice and assistance in order to do this. Although at this point in time there are many factors tending to limit the surgeon's ability to give such guidance, with an appreciation for what is known and for what can be foretold, the guidance can be given and this important element of our obligation to the combat arms fulfilled.

Section II. NUCLEAR ACCIDENTS AND INCIDENTS

4–8. GENERAL

We have had nuclear weapons in our inventory since shortly after World War II. Continuous handling, storing, and transporting these devices have resulted in a few nuclear accidents. However, safety devices and procedures are such that we have never had an unplanned nuclear yield result from an accident. We should define just what is a nuclear accident—anything that causes serious damage to a weapon or to a weapons system. A weapon involved in an explosion, conventional or nuclear, an accident resulting in radiological contamination or an accident resulting in potential or actual public hazard must be considered as an accident and handled as such.

4–9. SAFETY ASPECTS

a. **Personnel.** The initial process in attempting to preclude an accident or incident is to screen all personnel prior to schooling or assignment in the field of nuclear weaponry or reactors. This screening is performed under the provisions of AR 50–5. It includes a screening of medical records and evaluation of any conditions which could affect the performance of individuals in these obviously sensitive positions and would preclude selection for these assignments.

b. **Active Materials.** Active materials were discussed in lesson 1, but are repeated here for emphasis. In order to get the tremendous energy release which we know is available from nuclear weapons, certain active materials must be present. These are mainly uranium or plutonium and tritium. These materials are used both in our fission weapons and in our fusion or thermonuclear devices. In the fission process we bombard these heavy elements with neutrons in order to get a fission reaction with consequent release of neutrons, and fission fragments in a large amount of energy. In this process the large nuclei are broken into smaller fragments. On the other hand, in the fusion process, we are using light elements and with the proper application of tremendous pressure and temperature, bring them together or fuse them to produce slightly heavier elements, neutrons, and again, a tremendous release of energy.

c. **Critical Masses.** The basis of designing nuclear weapons safety is to prevent the formation of critical masses of fissionable material unless it is the intent to detonate the weapon. Let us now take a look at two possible weapon designs and see the real means by which safety is achieved. In other words, how do we prevent the formation of a critical mass at a time when it is not desirable? Keep in mind that from the time a weapon system is developed, safety is designed into it. Logical safety and specific methods of providing safety, then, are an integral part of weapons design.

(1) The gun-assembly type weapon is made so that its active material is separated into two subcritical masses at opposite ends of a "gun tube." Without a critical mass it is impossible to achieve a nuclear detonation. Various circuit-breakers are incorporated into the activating mechanism that detonates the propelling charge. This provides positive safety from the standpoint of pushing the two subcritical masses together in order to make a supercritical mass. Various natural safety devices, such as a physical block in the gun tube, could also be incorporated. A block of this type would have to be physically removed before the propelling charge could force the two subcritical masses together.

(2) In an implosion-type nuclear device, the active material is essentially all in one piece but it is still subcritical because the density of the active material is not high enough to achieve super-criticality. In this type of weapon the active material is surrounded by shaped high explosive charges. Each of these charges is designed to implode rather than explode upon detonation. Each of the high explosive shaped wedges has its own detonator and they must all be exploded or detonated <u>simultaneously</u> in order to compress the active material into a super critical mass to sustain a multiplying chain reaction and a subsequent explosion. The safety design here, of course, is the safety design of the electronic mechanisms used to detonate the high explosive detonators. The detonation of only part of the detonators will not result in the formation of a critical mass and, thus, will not result in a nuclear explosion. A partial high explosive detonation will probably blow the weapon apart and result in spread of the fissionable material in the immediate vicinity of the accident.

4—10. HAZARDS

a. Unexploded high explosives present the greatest initial hazard. This is because they may explode or at least become very sensitive so that any handling whatsoever may cause them to explode resulting in casualties of personnel in the vicinity. All of our weapons use high explosives to some degree. This material becomes extremely dangerous when subjected to fire or rough handling which may result from an accident. The high explosive may then burn or explode. If it does not burn or explode there may be melting of the high explosive and this melted product is much more sensitive and touchy than the original configuration. The presence of unexploded high explosives in a burning environment can generally be verified by noting torching white flames in and among the normal flames from a gasoline fuel fire. Chunks of unexploded high explosives gathered in the vicinity of an accident will generally be recognized by their yellowish color. Until emergency ordnance disposal personnel arrive and police up these chunks and pieces of unexploded high explosives, medical personnel must be extremely careful and cautious in retrieval of casualties from this area. Only personnel such as explosive ordnance disposal (EOD), specifically trained in the handling of this material, must be allowed to handle it at the accident site.

b. The second listed hazards at the nuclear weapon accident site are plutonium and uranium. These hazards are listed together because they are both heavy metals, both are radioactive, and both emit alpha particles. Of the two, plutonium is by far the greater biological problem and we will consider the hazard from plutonium knowing full well that uranium hazard will be taken care of in the consideration. These metals are not particularly hazardous within the configuration of an intact weapon; however, if a weapon has been in an accident and ruptured, plutonium contamination may be scattered on a relatively large area of ground. Under these circumstances there is always a possibility of contamination of anything in the area and the subsequent carrying of this contamination to other areas by the winds. The other primary source of plutonium or uranium hazard is a fire engulfing the weapon. Under these circumstances this material may become a fume and be carried away with the smoke from the fire constituting a large area problem depending on wind conditions. It is under these conditions that there is a great possibility of this material being inhaled by persons and animals who inadvertently get into the smoke cloud. Since both of these metals have an extremely long half-life the decontamination problem resulting from an accident becomes extremely difficult. In some instances very large areas of ground may have to be scraped, collected, and buried in a controlled area. The inhalation hazard may be minimized by using some sort of respiratory protection. The standard protective mask will serve the purpose.

c. A third potential hazard will be tritium, a radioactive isotope of hydrogen which emits a weak beta particle. As tritium is a light gas it diffuses rapidly in the air, and readily oxidizes to form tritiated water vapor. It does have some properties which make it an important hazard potentially associated with nuclear weapons accidents. In an open environment tritium will be rapidly dispersed in the atmosphere and present a problem only for a short period of time in the immediate vicinity of the accident. In an enclosed environment, however, tritium may be present in considerable

concentrations for relatively long periods of time and certainly must be considered as a serious hazard. Keep in mind that tritium, as tritiated water, may be readily incorporated into the body through the skin so that personnel working in this area must be required to wear full protective clothing impervious to water.

d. Lead and other metals such as beryllium may be present in small quantities as a result of a nuclear accident. These nonradioactive materials are certainly minor hazards compared to the potential from the previously discussed items. Public Health Service personnel, however, should be aware that they exist, particularly if the accident took place in the vicinity of a water supply. Since the possibility of a fission reaction taking place accidentally is remote, the possibility that fission fragments will exist is equally remote. Obviously, if fission reaction did take place, we have a fallout problem. However, since the possibility of an unwanted fission reaction is essentially zero we will not particularly consider that possibility in peacetime nuclear accident planning.

e. There are many factors that affect the relative hazard of radioisotopes taken internally into the body. Obviously, the quantity of the material entering the body is important. Equally important, probably, is the route of entry. Inhalation becomes a very serious problem with the subsequent deposition of this radioactive material in the lungs and possible absorption into the bloodstream. Many of the heavy radioisotopes commonly encountered are poorly absorbed from the gut and this becomes definitely a secondary route of entry. Other things such as the physical and chemical properties of the radionuclide, the metabolic pathway in the body, elimination, and biological half-life are important in assessing the relative toxicity or hazard from internally deposited radionuclides.

4-11. A NUCLEAR ACCIDENT

a. Since the likelihood of a nuclear accident is probably greatest while a weapon is being transported, let us now consider a nuclear accident resulting from a vehicle accident on a highway north of San Antonio. Accompanying the particular device will be a Courier Officer, an individual who has primary responsibility for that particular warhead in transit. He will have communications facilities available to him in his convoy as well as security personnel. After the accident has occurred, the courier or the senior surviving individual is responsible for contacting the commanding officer of the nearest military or government installation. That installation commander is responsible for furnishing all possible immediate support, such as additional security personnel or medical support to take care of casualties. The installation commander is also responsible for immediate notification of the Army Area Commander. In our example, the Fifth Army Commander would then assume responsibility for this accident through a nuclear accident and incident control officer or NAICO. The NAICO would be dispatched from the nearest Fifth Army installation and assume command at the accident site upon his arrival. To assist him in performance of his functions are several specialty teams as well as personnel to assist in specific areas.

b. There are teams which are furnished by the Department of Army upon request of the Army Area Commander through his NAICO. The first of these is a Radiological Advisory Medical Team or RAMT team. The RAMT team is a special team under the control of Health Services Command for the purpose of advising on radiological health criteria. The RAMT team is composed of one nuclear medical science officer (68B), RAMT Leader; one Nuclear medicine officer (60B, 61Q, 61R, or 61S), at least two specialists, MOS 91X20 or equivalent (91W20 or 91S20 with additional training); and additional personnel as determined by the RAMT Leader. The RAMT teams are positioned at Walter Reed Army Medical Center and the 7th Medical Command. The RAMT team performs the following functions: They monitor casualties for radiological health hazards and exposure level criteria, (personnel at local hospitals do not have the capability to conduct alpha monitoring); evaluate survey data in order to advise the NAICO on release of contaminated areas for general occupancy; monitor medical facilities and equipment where contaminated casualties have been evacuated, as requested by the medical facility commander, and advise on containment of radiological hazards and decontamination of exposed patients, medical personnel, and facilities. The RAMT team advises on pertinent, early and followup laboratory and clinical procedures and are prepared to assist with only absolutely essential emergency medical care should the need arise.

c. In addition to these special teams, organized and equipped specifically to support Army Nuclear Accident Plans, other personnel and equipment requirements are obviously going to be needed by the NAICO. The local medical facility will be required to evacuate, treat, and care for casualties or injured individuals at the site. Legal advice will become extremely important to the NAICO and a member of the Army Commander's legal staff will be furnished to the NAICO. Public information aspects become extremely important and a PIO specifically trained to handle nuclear accident information dissemination will be provided by the Army Area Commander. Security forces will be required to safeguard classified equipment and material until they are evacuated and to prevent unauthorized entrance of personnel into what may be radiologically contaminated areas. Obviously, emergency ordnance disposal will be required. Normally, an EOD individual specifically trained in the weapons system being transported accompanies the convoy.

4–12. SUMMARY

In planning for medical support of nuclear weapons accidents we must plan from the standpoint of very rigid peacetime radiation protection standards, which rigidly control the exposure of individuals and personnel to sources of radiation. We should be convinced that safety design is inherent in design of any nuclear weapon system. Safety considerations are developed along with technology for design of the remainder of the weapons system. In nearly three decades of transporting nuclear weapons we have not had an accidental nuclear yield. Unexploded high explosives is the most important initial hazard at the scene of the nuclear accident. Once the unexploded high explosive is policed by qualified personnel, the major hazard will be plutonium and uranium contamination, should it exist. The least likely of the hazards which will occur will be fission products because of the inherent safety design of nuclear weapons. Every local military and government

installation has the responsibility for providing what assistance they possibly can to a Courier Officer. This may be in the form of medical support, security forces, or communications. Basically, the Army Area Commander is responsible for assuring that appropriate action is taken when an Army owned nuclear weapon is involved in an accident in his geographical area. He exercises his responsibility through a nuclear accident and incident control officer. The NAICO has at his disposal specialized teams, such as the Radiological Advisory Medical Team, to assist him in exercising his duties. Additionally, legal and public information, security, emergency ordnance disposal and other support is available from the Army Area commander.

EXERCISES, LESSON 4

REQUIREMENT. Answer the following exercises by marking the lettered response that best answers the question; or by completing the incomplete statement; or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson, and check your answers with the solutions.

1. In any situation, but particularly in a mass casualty situation, what is an effective individual? An individual who is:

a. Fearful.

b. Careful.

c. Fearless.

d. Capable of performing an assigned task.

e. Motivated to such a high degree that no task is impossible.

2. From the operation exposure guide table, it can be seen that a radiation exposure status of RES-2 places a unit in a single exposure criteria of _____ for any further exposure.

a. Negligible.

b. Moderate.

c. Emergency.

3. An individual who is at 10 percent physical effectiveness would normally be considered capable of which of the following tasks?

a. Firing a preplaced weapon.

b. Driving a vehicle.

c. Aiming a weapon.

d. Hand-to-hand combat.

4. Generally about what portion of a unit is incapacitated if it is considered ineffective?

a. 1/2.

b. 1/3.

c. 1/4.

d. 1/10.

5. Which of the following constitute(s) radiological rest for a combat unit?

a. All of the choices below.

b. Removing the unit to a non-combat area in the theater of operations.

c. Suspending duty activities immediately after the unit is irradiated.

d. Sheltering the unit in radiation shelter.

6. What constitutes the major initial hazard in dealing with nuclear accidents?

a. Plutonium.

b. Unexploded high explosive.

c. Uranium.

d. Tritium.

7. If the radiation exposure status of a unit is RES-2, the total past cumulative dose is about _____ rad.

a. 25.

b. 100.

c. 200.

d. 250.

8. By an acute dose, we mean the total radiation dose accumulated:

a. During the first 5 minutes after a nuclear detonation.

b. During the first hour after a nuclear detonation.

c. During a 24-hour period.

d. Over a period of three weeks.

9. Which of the following is the appropriate action to be taken by a commander who knows that his troops have received a radiation dose which will probably be lethal?

a. Get as much out of them as possible as long as they are at least somewhat effective.

b. Evacuate all of them immediately regardless of the mission.

c. Evaluate the urgency of the mission against possible chances of recovery and make his decision based on his best judgement.

10. Who should assume command and control at the immediate site of a nuclear accident?

a. The Courier Officer.

b. The Army Commander.

c. The Radiological Advisory Medical Team leader.

d. The Nuclear Accident and Incident Control Officer.

SOLUTIONS TO EXERCISES, LESSON 4

1. d (para 4–3a)
2. c (Table 4–3)
3. a (Table 4–1)
4. b (para 4–3b)
5. d (para 4–4e(4))
6. b (para 4–10a)
7. b (Table 4–3)
8. c (para 4–2c)
9. c (para 4–4b(4))
10. d (para 4–11)

LESSON ASSIGNMENT SHEET

LESSON 5	--Medical Operations in Fallout.
LESSON ASSIGNMENT	--Paragraphs 5-1--5-24.
MATERIALS REQUIRED	--Map, Helotes, 1:50,000; overlay, simplified fallout predictor attached in rear of subcourse booklet).
	--Before you study the Problem Situation in Section II of the text assignment, "set up" the map and overlay for easy quick referral. Become familiar with the locations of units before you begin the step-by-step instruction for this specific situation.
LESSON OBJECTIVES	--After completing this lesson, you should be able to:
	5-1. Construct a simplified fallout predictor.
	5-2. Describe current concepts of medical operations in fallout to specific situations.
SUGGESTION	--After completing the lesson assignment, complete the exercises of this lesson. These exercises will help you achieve the lesson objectives.

LESSON 5

MEDICAL OPERATIONS IN FALLOUT

Section I. BACKGROUND

5–1. INTRODUCTION

a. Successful medical operations on the nuclear battlefield require timely and knowledgeable decisions. Surgeons, unit commanders, and staff officers must understand the problems imposed by a nuclear environment. Decisions concerning how to minimize the effect of blast, thermal radiation, and initial nuclear radiation must be made in advance of the event. Those things which must be accomplished to minimize the prompt effects are simple and straightforward: dispersion, shelter, and avoidance of likely nuclear targets. Once a bomb has exploded, there is little one can do to alter the number of casualties which may be produced.

b. In the case of fallout, things are quite different. The fallout radiation hazard may cover thousands of square kilometers and persist for many hours or even days. There is not only time to make decisions but a vital necessity that they be made. These decisions will not merely affect the outcome, they will determine it.

5–2. PRIMARY PROBLEMS IN FALLOUT

Medical personnel and medical units generally will be faced with two primary problems when operating in a significant local fallout situation. The first of these is unit survival and the second is the performance of the mission.

a. **Unit Survival.** To survive in a fallout situation the existence of the hazard must first be recognized. Information pertaining to the location and intensity of radiologically contaminated areas may be provided the medical units by higher headquarters. In all probability, however, medical units will receive little warning of impending fallout. Even if this information were available in sufficient time to the medical unit, it would not necessarily represent the key to action. It will be the unit NBC Defense team which will determine the presence or absence of fallout, collect and analyze the radiac data, and assist the medical commander in formulating decisions as to the actions necessary for unit survival. The unit team will make use of radiac instruments in dealing with fallout radiation hazards. Some of the radiac instruments available to a combat support hospital are the Radiac set AN/PDR–27, Dosimeter Charger PP–1578A/PD, Tactical Dosimeter IM–93/UD and Radiacmeter IM–174A/PD.

b. **Performance of Mission.**

(1) Should evacuation of patients to a shelter area become necessary, professional care has to revert to simple supportive measures and surgical procedures limited to those urgently required to save life and limb.

(2) Personnel should remain in shelter during fallout unless specifically authorized to leave shelter sooner to perform a specific task. Prior to authorized departure from shelter during fallout, the departing individual should be briefed by monitoring personnel on precautions to be observed and he should have a radiac dosimeter attached to his clothing. Rotation of personnel who leave the shelter should be practiced.

(3) Unit NBC Defense personnel should make radiation background readings in the open. The radiological situation inside the shelter should be determined early. While transmission factors of typical shelters have been computed and are shown in Appendix A, GR 76-332-100, page A-8, the actual protection should be determined with the proper instruments.

5-3. CONTAMINATION OF FOOD, WATER, PERSONNEL, AND MATERIAL

a. **Food and Water.** After a nuclear attack, in addition to protection from external radiation exposure, it is important that personnel in the fallout area be protected from internal radiation exposure due to the ingestion of radioactively contaminated food and water. Although the ingestion of contaminated food and water is not an immediate threat to survival, there is the possibility of late somatic and genetic effects. It is essential, therefore, that every effort be made to remove the radioactive material from food and water prior to consumption to prevent this material from getting into the body. Such procedures, however, should not interfere with tactical operations. All unpackaged and uncovered foods, such as vegetables, fruits, and carcass meats, should be considered contaminated if obtained from a known fallout field. These things can be decontaminated by washing, trimming, or peeling the outer skin or leaves. Nonperishable items that cannot be readily decontaminated, such as flour, sugar or salt, can be set aside allowing natural radioactive decay to reduce the radioactivity to acceptable levels. If food supplies are critically low, contaminated food may have to be consumed. In this event, it may be advisable to dilute the contamination by mixing with uncontaminated food. This will reduce the total amount of radioactivity to a level where exposure will be minimal. Boiling or cooking contaminated food has no effect in removing that fallout material. In packaged containers, such as cans, fiberboard, and cellophane, most of the contamination is not in the food but on the package. This simple expedient of brushing or washing the dust from the container will remove most of the radioactive material. The ingestion of contaminated water can be avoided if certain precautions are taken. Water in canteens, tanks, cans, or other sealed sources will not be contaminated by fallout and will be safe for drinking. The same is usually true for water from ground sources, such as wells, and spring water. Water in bottles, covered reservoirs, and other containers will be free from radioactive contamination. Water in streams is more likely to contain less radioactivity than that from lakes and ponds due to dilution. Water drawn from below the surface will contain relatively low concentrations of radioactivity.

b. **Personnel.** The radiological decontamination of personnel should be accomplished as soon as the situation permits. If there is time and the tactical situation permits, personnel should bathe, using plenty of soap and water, preferably warm. Particular attention should be given to skin creases,

hairy parts of the body, and the fingernails. After decontamination is adequate, as determined by monitoring, personnel should be issued clean clothing. Personnel decontamination stations or quartermaster shower facilities should be used whenever possible. When personnel are prohibited by the tactical situation from using the normal decontamination procedures, they may use field expedient procedures to include shaking and brushing of clothing. Personnel should wipe all exposed skin with a damp cloth and remove as much radioactive dust as possible from the hair and from under the fingernails.

c. **Material.** Medical equipment and facilities are also subjected to contamination.

(1) Clothing. Decontamination of clothing is a primary mission of supply and service units and chemical processing units. In emergencies, personnel or units may be required to decontaminate their own clothing. This is accomplished during personnel decontamination or whenever possible, following as nearly as possible general laundering procedures. Rubber and leather items are decontaminated by washing with detergent and water.

(2) Vehicles and equipment. The method most desirable for the decontamination of vehicles and equipment is aging. This method can be used only when there is not an immediate need for the vehicle and the contaminant is not too long lived. Brush loose, dry contamination from the vehicle before starting the aging process to preclude adsorption of radioisotopes which become dissolved in rainwater or other moisture. In the event that the vehicle is required for early use, brush loose contamination from the surface and clean the vehicle by washing and scrubbing with steam or water and detergents.

(3) Roof and walls of buildings. Buildings should be decontaminated by aging unless required for operations. Contamination of buildings will generally be in dust form (fallout). It should be removed by hosing the building with water. This procedure is especially effective if the building has a smooth sloping roof and smooth-finished sides. The removal of lightly adsorbates contamination is aided by scrubbing with or without detergents. A flat-roofed building is decontaminated in the same manner but with some difficulty. Cinder and tar or asphalt tile roofs will physically trap some of the contaminant. Although the wet procedure is the most practical method for buildings with brick or stone walls, water carries some of the contamination into the surface pores.

5-4. EVALUATION OF RADIATION CONTAMINATION

a. Under the threat of or actual conditions of nuclear warfare, units in the field must continuously evaluate the impact that enemy use of nuclear weapons has on the conduct of operations and be prepared for contingency action to reduce the disruption caused by a nuclear attack. Fallout may be employed to blanket areas of poorly defined targets, create obstacles, canalize movement, disrupt conduct of operations, and force relocation of support installations. Casualty-producing levels of fallout can extend to greater distances and cover greater areas than most other nuclear weapon

effects and can, therefore, influence actions on the battlefield for a considerable period of time. Knowledge and understanding by commanders and individuals at all levels of the radiological contamination aspects will permit the commander to determine accurately the advantages and disadvantages of each course of action open to him in the execution of assigned missions.

b. The dose rate at any location within a contaminated area does not remain constant but decreases with time. Thus, in time radiation hazard will be of no military significance. The rate at which this decay takes place also varies with time, generally becoming slower as time passes. The decay rate for contamination in an area depends upon many factors and generally cannot be accurately determined until several series of dose-rate readings are available for specific locations within the contaminated area. Standard decay conditions are therefore assumed by all units until actual conditions are determined or until higher headquarters directs otherwise. (A decay exponent of 1.2 has been established as standard and is used by all units unless they have been informed otherwise by higher headquarters.)

5-5. THE FALLOUT AREA

Fallout areas will be the largest of the contaminated areas produced on the battlefield. One particularly important aspect of fallout is that the direction of fallout from ground zero is based upon winds aloft as well as upon surface winds. Thus, the actual location of fallout can differ appreciably from that which might be expected from the direction of surface winds.

a. **Automatic Fallout Response.** The rapid onset of fallout, especially from small yields, within a few kilometers of ground zero of a surface burst requires quick adoption of protective measures. The time after burst before onset of fallout near ground zero will vary, depending on the yield of the nuclear detonation, weather conditions, and type of terrain. Normally, use of shelter will be automatic whenever nuclear bursts are observed, since these bursts should be assumed to be fallout producing until monitoring and the passage of time prove otherwise. During the period of uncertainty, precautionary measures consistent with the mission are instituted.

b. **Physical Recognition of Fallout.** Particles are often visible during hours of daylight. The arrival and settling of dustlike particles after a nuclear burst occurs should be assumed to indicate the onset of fallout unless monitoring shows no radiation in the area.

5-6. DOSE RATES

a. **Ground Dose Rates.** The ground (outside) dose rate is the unshielded dose rate measured 1 meter above ground level (about waist high). This dose rate approximates the average whole body dose rate a man would receive if he were standing in the open in the contaminated area at the location of the measurement. Ground dose rates are the basic reference used to determine the magnitude of a contamination hazard. All dose rates mentioned in radiological intelligence are ground dose rates unless otherwise specified. Thus, all dose-rate information obtained under conditions that

would modify the ground dose rate would be converted to ground dose rates for radiological intelligence purposes.

b. **Factors Affecting Determinations of Ground Dose Rates.** Because some radiation is shielded out, the dose rate inside a vehicle or shelter is lower than the ground dose rate at that location. The degree of shielding depends on the type of vehicle or the construction of the shelter. Dose rates measured in an aircraft flying over a contaminated area are lower than the corresponding ground dose rates because of the shielding effect of the air and the aircraft.

c. **Transmission Factors.** A transmission factor (TF) is a measure of the degree of shielding afforded by a structure, vehicle, fortification, or a set of specified shielding conditions. The transmission factor is that fraction of the outside (ground) dose or dose rate which is received inside the enclosure which provides the shielding. Transmission factors of common types of vehicles, structures, or fortifications are contained in the Appendix A, GR 76-332-100, p. A-3. These transmission factors were established, in the case of a combat vehicle, by determining the shielded dose or dose rate for the most exposed occupant location and, in the case of a structure or fortification, by determining the shielded dose or dose rate at approximately the center of the shielded volume. Transmission factors determined in the field require two dose-rate readings taken about the same time within 3 minutes; one will be an outside (ground) dose-rate (OD) reading and the other an inside (shielded) dose-rate (ID) reading. The transmission factor can then be calculated using the formula below:

$$\text{Transmission factor} = \frac{\text{Inside dose or dose rate}}{\text{Outside dose or dose rate}} \quad \text{or}$$

$TF = \frac{ID}{OD}$ and by mathematical rearrangement: $ID = TF \times OD$ and $OD = \frac{ID}{TF}$

5-7. ILLUMINATION TIME

As a field expedient, yield may be estimated from the measurement of the illumination time of a nuclear burst, especially during hours of darkness or poor visibility. However this method should be used only if it is impossible to obtain cloud parameters since this method only gives a yield estimate on the order of a factor-of-10. Techniques for measuring illumination time will vary, depending on the situation, but under no circumstances should the observer attempt to look directly at the fireball since this can result in permanent damage to the eyes. The illumination time may be estimated by the observer who has taken shelter in a foxhole by noting the light reflected into the foxhole. The observer can look at the floor of the foxhole and still sense the duration of the flash or reflected light. Counting in seconds will probably be the most effective way of determining the illumination time since the "dazzle" (flash blindness) effect will preclude the reading of watches. Page A-33, Appendix A, GR 76-332-100, shows rough estimations of yield, using illumination time.

5–8. SIMPLIFIED FALLOUT PREDICTION

a. **General.** To satisfy command requirements at all echelons, two procedures for predicting fallout from a single detonation are established as explained below.

(1) The primary procedure consists of a detailed method to be employed by the Nuclear, Biological, and Chemical Element, (NBCE) in preparing fallout predictions for use by major commands and subordinate units.

(2) The supplemental procedure consists of a simplified method that can be used by any unit. The simplified method employs a simplified fallout predictor which may be either the standard Area Predictor, Radiological Fallout, M5, (see FM 3–22, para 31) or a field constructed simplified fallout predictor. In a nuclear war, it may be expected that small, mobile units will be operating in widely dispersed areas. In such situations, receipt of a detailed fallout prediction (NBC 3 (Nuclear) report) from major command headquarters may be delayed for significant periods of time. The supplemental procedure provides small units an immediate capability of estimating the location of a potential fallout hazard, thereby allowing greater unit self–sufficiency. The estimate made of the fallout hazard using the simplified method will be less accurate than that made using the detailed method.

b. **Significance of Predicted Fallout Zones.**

(1) Inside the predicted area. In both simplified prediction and detailed prediction, the predicted zones define those areas within which exposed, unprotected personnel may receive militarily significant total doses of nuclear radiation (that which may result in a reduction in their combat effectiveness) after actual arrival of fallout. A zone of primary hazard (Zone I) and one of secondary (Zone II) are predicted.

(a) Zone I delineates the area of primary hazard and is called the Zone of Immediate Operational Concern. It is defined as a zone within which there will be areas where exposed, unprotected personnel may receive doses of 150 rad (the emergency risk dose), or greater, in relatively short periods of time (less than 4 hours after actual arrival of fallout). Major disruptions of unit operations and casualties among personnel may occur within portions of this zone. The actual areas of major disruption are expected to be smaller than the entire area of Zone I; however, the exact locations cannot be predicted. The exact dose which personnel will receive at any location inside Zone I is dependent upon the dose rate at their location, the time of exposure, and protection available. There is, however, a reasonably high assurance that personnel outside the boundary of Zone I will not be exposed to an emergency risk dose in less than 4 hours. The radiation produced from neutron–induced activity will be closely confined to the area around ground zero, which will be well within the limits of Zone I. The induced radiation will therefore have no effect on the extent of Zone I but will cause higher dose rates in the area around ground zero. Thus, the dose from induced radiation was not considered in determining the extent of Zone I.

(b) Zone II delineates the area of secondary hazard and is called the Zone of Secondary Hazard. It is defined as a zone within which the total dose received by exposed, unprotected personnel is not expected to reach 150 rad within a period of 4 hours after the actual arrival of fallout, but within which personnel may receive a total dose of 50 rad (the negligible risk dose), or greater, within the first 24 hours after the arrival of fallout. However, only a small percentage of the personnel in the zone are expected to receive these doses. The exact dose personnel will receive at any location within Zone II is dependent upon the dose rate at their location, the time of exposure, and protection available. Personnel located close to the extent of Zone I will normally receive higher doses than those located close to the extent of Zone II. Personnel with no previous radiation exposure may be permitted to continue critical missions for as long as 4 hours after the actual arrival of fallout without incurring the emergency risk dose. If personnel in this zone have previously received significant radiation doses (a cumulative dose of 150 rad or more), serious disruption of unit mission and casualty-producing doses may be expected.

(2) Outside the predicted area. Outside the predicted area, exposed, unprotected personnel may receive a total dose that does not reach 50 rad in the first day (24 hours) after actual arrival of fallout. The total dose for an infinite time of stay outside the predicted area should not reach 150 rad. Therefore, outside the predicted area, no serious disruption of military operations is expected to occur if personnel have not previously been exposed to nuclear radiation. Appreciable previous exposure should be considered. In either case, periodic monitoring coupled with routine radiological defense measures will normally provide adequate protection.

c. **Description of Fallout Prediction Method.**

(1) The simplified fallout prediction method is provided to enable small unit commanders to make an immediate estimate of the location of the potential fallout hazard without waiting for a detailed fallout prediction message from the NBCE's of major commands.

(2) The simplified prediction method requires nuclear burst information, a current effective wind message, and a simplified M5 Fallout Predictor (or the construction of a simplified predictor).

(3) The lateral or angular limits of the simplified fallout predictor are fixed at 40 degrees; this is in contrast to the determination of lateral limits from current winds in the detailed method. These fixed angular limits are based upon climatological studies. Thus, the simplified method provides the small unit commander with an "order of magnitude" estimate of the lateral limits of the area of hazard. However, both the simplified prediction method and the detailed prediction method use the effective wind speed in the same manner. Therefore, both methods present the same degree of accuracy in downwind distance.

d. **Effective Wind Message.**

(1) Use of the simplified fallout predictor (or construction of one) requires knowledge of the effective wind speed and direction. This information is prepared by the NBCE as an effective wind message and is transmitted down to company level each time new upper air wind data are received. Since the effective wind speeds and directions vary with yield, six wind speeds and directions are transmitted, corresponding to the six preselected yield groups. Effective wind messages more than 12 hours old should be used with caution for fallout prediction.

(2) The format for the effective wind message will be a series of seven lines, preceded by the phrase "Effective Wind Message," as follows:

Effective Wind Message

ZULU —DDtttt (local or ZULU, state which)
ALFA —dddsss
BRAVO —dddsss
CHARLIE —dddsss
DELTA —dddsss
ECHO —dddsss
FOXTROT —dddsss

(3) The significance of each line is as indicated below:

(a) ZULU DDtttt—This line is the date and time at which the winds were measured, with DD the day and tttt the hour in local or ZULU time (GMT).

(b) The remainder of the lines provide data for the six preselected yield groups, where ddd is the effective downwind direction in degrees from grid north and sss is the effective wind speed to the nearest kilometer per hour.

1. ALFA dddsss is the data line for the 2-kiloton (KT) or less yield group.

2. BRAVO dddsss is the data line for the more than 2-KT through 5-KT yield group.

3. CHARLIE dddsss is the data for the more than 5-KT through 30-KT yield group.

4. DELTA dddsss is the data line for the more than 30-KT through 100-KT yield group.

5. ECHO dddsss is the data line for the more than 100-KT through 300-KT yield group.

6. FOXTROT dddsss is the data line for the more than 300-KT through the 1 megaton (MT) yield group.

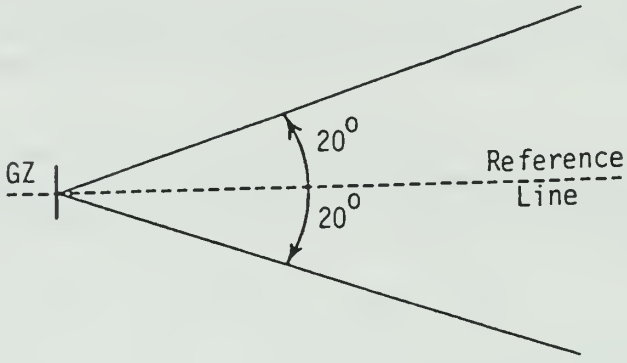
(c) For example, if the DELTA line of an effective wind message read DELTA 090025, the person using this information would know that the DELTA line is used when the yield of the weapon is in the range from 30 KT through 100 KT. The contents of this DELTA line would indicate that the fallout prediction would be determined from an effective wind speed of 25 kilometers per hour and an effective downwind direction of 90 degrees.

e. **Field Construction of Simplified Fallout Predictor.**

(1) If the fallout predictor (M5A2 radiological fallout area predictor) is not available, a predictor can be constructed from any pliable, transparent material, and to any desired scale, by the following procedure:

(a) Step 1. On a piece of pliable, transparent material, draw a thin dotted line (reference line) to a scaled length of 50 kilometers from a point selected to represent ground zero. This would appear as below:

(b) Step 2. Draw two radial lines from ground zero at angles of 20 degrees to the left and right of the dotted reference line, as below:



(c) Step 3. On the side of ground zero opposite the reference line, draw a series of concentric semicircles (using the selected map scale) having radii of 1.2 kilometers, 1.9 kilometers, 4.2 kilometers, 6.8 kilometers, 11.2 kilometers and 18.0 kilometers, which correspond to stabilized cloud radii from nuclear bursts with yields of 2 KT, 5 KT, 30 KT, 100 KT, 300 KT and 1000 KT (1 MT), respectively (fig. 5–1).

(d) Step 4. Label the semicircles constructed in step 3. Starting with the line closest to GZ and moving up from GZ, label the lines A, B, C, D, E, and F; moving down from GZ, label the semicircles 2 KT, 5 KT, 30 KT, 100 KT, 300 KT, and 1000 KT (1 MT), respectively (fig. 5–1).

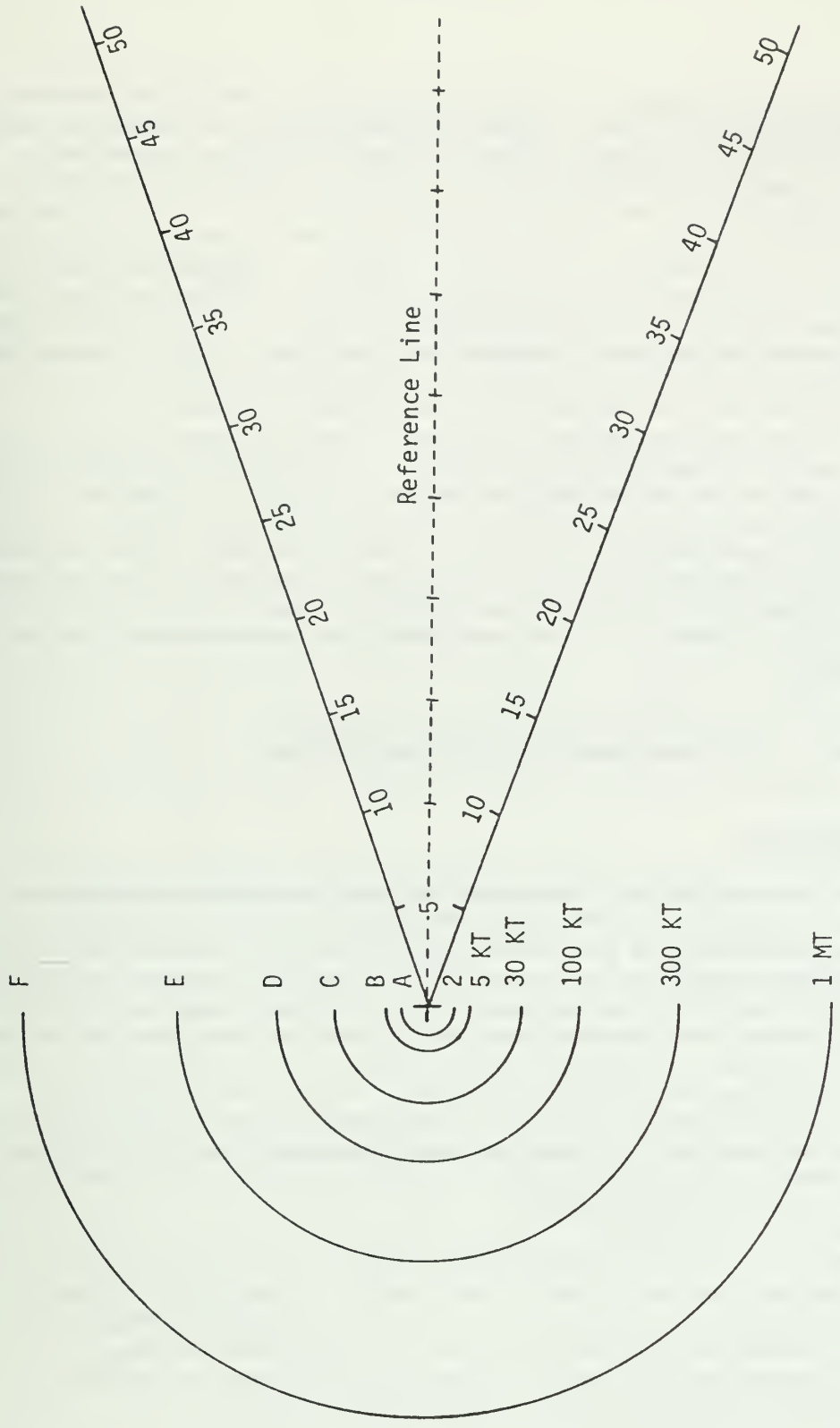


Figure 5–1. Simplified fallout predictor, field construction (not drawn to scale).

(2) To use the field-constructed fallout predictor, determine the downwind distance of the Zone of Immediate Operational Concern from nomogram, Appendix A, GR 76-332-100, page A-36. This determination is made by connecting the value of the effective wind speed and the point on the yield/scale representing the yield with a straightedge. The value of the downwind distance of Zone I, in kilometers, is read at the point of intersection of the straightedge and the Zone I downwind distance scale. The downwind distance of Zone II is twice that of Zone I. Arcs are then drawn between the two radial lines, using GZ as center, with radii equal to the two downwind distances determined. Tangents are now drawn from the cloud radius line for the yield group to the points of intersection of the radial lines of the predictor with the arc representing the downwind distance of Zone I. Zones I and II are now labeled and the radial lines between the two downwind arcs and the cloud radius line are drawn in. Time-of-arrival arcs of interest are drawn in, using the effective wind speed. The scale of the fallout predictor and the map must be the same. The resulting prediction is then oriented by placing a protractor over an actual or assumed GZ on the map and drawing a line to represent the effective wind direction for the yield group of interest. Place ground zero of the predictor over ground zero on the map and rotate the predictor until its reference line coincides with the effective wind direction.

Section II. PROBLEM SITUATION

5-9. INTRODUCTION

a. The problem situations and solutions which follow represent an effort to "bring together" information which may have been learned over a period of time and which is considered to be a minimum background for a medical commander or staff officer in providing medical support and advice to an infantry division under nuclear warfare conditions. Medical service support in a nuclear environment is a highly complex operation and extremely vital to the commander's success in battle as well as to the morale of the soldier. In the event of tactical employment of nuclear weapons, the commanding officer or staff officer of a medical unit will need to know how to successfully evaluate the radiological hazards encountered in the combat zone from the employment of nuclear weapons and radiological fallout so that the medical mission may be accomplished.

b. While we at the Academy realize that this method of "talking through" situations and solutions is not ideal, it does present specific problems a commander may experience and gives the student a chance to think through the problems before the solutions are presented. Perhaps in no other way could so much be brought to the attention of the stuoent in terms of specific problems and situations in such concise form.

c. Under normal classroom procedures, the construction of the simplified fallout prediction would be accomplished on the overlay as described in the step-by-step directions in the Appendix A, GR 76-332-100, page A-31 and paragraph 5-8 above. Due to some limitations of the

correspondence method of instruction, the map and completed overlay are furnished in order that the student may have a "true" picture of the units and their locations, in relation to ground zero. If you trace the step-by-step directions as given, you will be able to ascertain how the overlay was constructed.

5-10. GENERAL SITUATION

a. The Fifth (U.S.) Army has been required to defend its geographical area of command responsibility against Aggressor Forces advancing from the West.

b. One month ago this date, a strong Aggressor Force with the help of U.S. Sympathizers overran the southwestern border defenses in the area of Nogales and Douglas, Arizona, and have attacked in two main axes within striking distance of Los Angeles from the East and San Antonio from the West. The apparent overall plan is to gain a sufficient footnold within the southwestern part of the United States to include Gulf and West Coast ports by taking control of New Orleans and San Francisco, sue for a cessation of hostilities in the interest of "peace," and so influence the political picture of the U.S. Government that through "peaceful coexistence" eventual control of the Government can be obtained by covert means. Phoenix, Tucson, and El Paso have been occupied by the Aggressors. The Aggressor's western push has been unhampered by large military forces, but substantial resistance was encountered east of El Paso. National Guard and Reserve Forces have been called to active duty.

c. Though Aggressor Forces do not have air superiority over the combat zone, they have available sufficient numbers of aircraft to employ nuclear weapons. These aircraft were obtained through Aggressor mutual assistance pacts or they are captured U.S. aircraft obtained by Aggressor sympathizers which were employed on U.S. Air Force bases. Of particular note is the Aggressor Forces' fanaticism for their cause due to political indoctrination which has resulted in some suicide missions by both their ground and air forces.

d. Aggressor Forces have tactically used nuclear weapons up to 50 KT yield by such delivery means as 155 mm Howitzer, 203 mm gun Howitzer, 250 mm mortar, rockets, and aircraft. Also, atomic demolition munitions (ADM) have been used by infiltrators within some cities and military bases. However, on the whole, destruction of city complexes has been held to a minimum through the use of chemical agents in consideration of post-hostility reconstruction.

5-11. SPECIAL SITUATION

a. The 98th Combat Support Hospital (CSH) is in support of the 36th Infantry Division in defense of San Antonio with its numerous military installations. Military intelligence evaluates the Aggressor's strength in its Eastern force to be about three (3) Divisions which maneuver their forces in battalion size units. In spite of the losses suffered by the Aggressor Forces, their strength has been increasing due to U.S. revolutionary volunteers encouraged by the prospects of sharing in the mass looting which

has occurred in overrun areas. Currently, the 1st and 2d Brigades (Bde), 36th Inf Div, are in defensive positions along the forward edge of the battle area (FEBA) which extends on a line north-south 22 km west of Camp Bullis. The 3d Bde, 36 Inf Div with the 1st Bn, 504th Armor attached, is in reserve.

b. Reference to IX Corps directives reveals a maximum acceptable normal operational level of exposure to residual nuclear radiation of 4 rad/hr for subordinate units while in a defensive position. Ten (10) rad/hr maximum exposure when in attack or retrograde movement is authorized.

c. Location of units at 0900 hrs, this date (Ref: Map, Helotes, 1:50,000):

HQ, 3d Bde, 36th Inf Div—vic NH 273861—Assume dispersion of troops in each Bde within an area 3 km in radius from the C.P. 98th CSH—NH 361758
HQ, 36th Engr Bn—NH 313817

d. Mission: 98th CSH provides effective resuscitative surgery and medical treatment necessary to prepare critically injured or ill patients received from division medical elements for further evacuation; and in the event of an enemy NBC attack resulting in large numbers of patients, to be utilized in a manner comparable to that of an evacuation hospital.

e. The 98th CSH closed in position 0600 hrs and became operational at 1000 hrs, this date.

f. CO, 98th CSH is in the process of making a liaison visit to the CO, Engr Bn. You are the medical operations assistant of the 98th CSH.

g. The patient census of the 98th CSH at 1500 hrs, this date, is ten (10) litter patients who are awaiting evacuation by air to Brooke Army Medical Center at 1600 hours this date.

h. Preliminary reconnaissance of your area discloses an abandoned, dilapidated one-story frame farmhouse with a 7 x 13 meter wide cellar with a ceiling 4 meters high at NH 357759 and an old root cellar 4 x 5 meters wide and 2 meters high some 30 meters away from the house.

i. It is now 1518 hrs, this date. Your CO is still located at the Engineer Bn Tactical Operations Center. Elements of the Engineer Bn have just submitted some nuclear burst information and he has relayed the data to you for your information.

"Nuclear detonation observed to N.W. at 1515 hours.
Mushroom stem observed 312° Magnetic.
Flash-to-bang time about 18 seconds.
Illumination time about 2 seconds."

5-12. FIRST REQUIREMENT

a. What preparations should you have had the unit make considering the Aggressor's use of nuclear weapons?

(1) Determine possible shelter locations.

(2) Determine where, how, and when hospital personnel and patients will take shelter.

(3) Allocate supplies necessary for proposed shelter.

(4) Check operational status of RADIAC instruments.

(5) Review standing operating procedures (SOP) for radiological operations.

b. What was the yield of the nuclear weapon?

10 KT, as determined by an illumination time of 2 seconds. Ref: Appendix A, GR 76-332-100, p. A-33.

c. How far was the detonation from the engineer battalion?

Approximately 6 km (the speed of sound travels at approximately 330 meters per second or 1 km in 3 seconds).

d. What initial effects from the nuclear detonation would be experienced by the 3d Bde and its attached Armor Bn? Consider the troops located at 1,000; 2,000; and 3,000 meters from Ground Zero.

Since a low airburst detonation maximizes the three initial effects of the weapon it would be best, at this point, to assume a low airburst.

Radius (meters)	Psi	Cal/Sq/cm	RAD
1,000	6.1 (95 MPH Wind)	26 (3° Burns)	1600
2,000	2.1 (30 MPH Winds)	5 (2° Burns)	14
3,000	1.1 (18 MPH Winds)	2.1 (no Burns)	Negl

From this data it is readily apparent that troops in the open at 1,000 meters will have secondary missile injuries, severe burns, and lethal radiation exposure. Even troops protected in foxholes will receive an LD 50/30 of approximately 400 rad (1600 rad x 0.25). The TF of 0.25 is the approximate transmission factor for initial nuclear radiation in earth. At 2000 meters only exposed personnel will be casualties (2° burns). At 3,000 meters no casualties would be expected. Members of the Armor Bn who were in their tanks at the moment of the detonation would not have been injured by blast or thermal effects at any of the three distances. At 1,000 meters personnel protected in tanks would receive some radiation dose; however, this dose cannot be quantified unless the tank transmission factor for initial

nuclear radiation is determined. The charts and graphs in Appendix A, GR 76-332-100, page 3, give TF values for residual radiation only.

e. What initial effects (blast, thermal, and combined nuclear radiation) from the nuclear detonation would be experienced at the CSH?

None. Ref: Appendix A, GR 76-332-100, pages A-40,41,42.

f. Do you have sufficient information to make a fallout prediction plot if it is a surface burst? If not, what other information would you need?

No, you cannot make a fallout prediction yet because you do not have any wind direction or speed information. You do have an estimated ground zero and yield estimation. A current "Effective Downwind Message" would give the wind information that is needed to make a prediction. Furthermore, the type of burst is still uncertain.

g. Would you begin monitoring? Why?

Yes, continuous rather than periodic monitoring with the IM-174A/PD should be done. This means turning the instrument on and operating it continuously and frequently, perhaps every 5 or 10 minutes as determined by the CO, reporting a dose rate reading. Such continuous monitoring should be done when:

(1) A fallout warning is received.

(2) CO orders monitoring to begin.

(3) Nuclear detonation is heard.

(4) Unit is moving on a nuclear battlefield.

(5) Nuclear detonation has been observed, or reported.

(6) A reconnaissance or patrol is made on a nuclear battlefield.

(7) Radioactivity is greater than 1 rad/hr as determined by periodic monitoring.

h. What radiac instruments are available in the 98th CSH that you could use to monitor for fallout?

Use the IM-174A/PD to monitor for fallout in an area. Ref: Appendix A, GR 76-332-100, page A-20.

5-13. SPECIAL SITUATION CONTINUED

a. At 1500 hours, this date, the following Effective Downwind Message was received via telephone from S3, Med Bn:

ZULU DD1900Z
ALFA 120005
BRAVO 121010
CHARLIE 123020
DELTA 133056
ECHO 146025
FOXTROT 190080

NOTE: Six (6) hours is added to local San Antonio time (Sierra time) to get Greenwich Mean Time (Zulu time).

b. At 1524 hours this date, another telephone message from the CO, 98th CSH is received:

"The detonation: Surface Burst.
Am returning to unit immediately. Prepare recommendations as to the need for hospital personnel to prepare and/or take cover in fallout shelters at the 98th CSH."

5-14. SECOND REQUIREMENT

a. What is your recommendation to the CO?

Before a recommendation to the CO, 98th CSH can be made, a determination must be made as to the possible radiological hazard which may result from this nuclear detonation. The two problems of concern are first, taking cover if radiological contamination from the fallout will probably occur and second, disruption of the medical mission should there, in fact, be no need to take shelter. These questions can be somewhat resolved by preparing a fallout prediction; therefore, a fallout prediction must be prepared to determine the need to take cover in the fallout shelters. If a fallout prediction has not been made as yet, it needs to be prepared now. If a fallout prediction has been prepared, its validity is established by the information that the nuclear detonation was a surface burst. Evaluation of the prepared fallout prediction will establish the fact that the 98th CSH is in Zone I; as such, the recommendation should be to "Prepare to take cover" in the fallout shelters immediately. It is obvious that time would have been saved had a tentative fallout prediction been prepared prior to the actual knowledge that the detonation was a surface burst.

b. Would you report this new radiological intelligence? Why? To which headquarters?

No, because this information was not determined by you. Also of consideration at this time is a probable overloading of communications, and your information, which is hearsay, would add to this problem. However, if you did decide to report this information you would report it to the Med Bn and your parent Medical Gp.

c. Prepare an NBC 3 (Nuclear) Report from the above information. (Ref: Appendix A, GR 76-332-100, pages A-6 thru 8, A-31,32 or FM 21-40, pages 6-8 through 6-28).

Precedence:	IMMEDIATE
Date/Time:	DD 21ttZ
Security Classification:	Unclassified
From:	98th CSH
To:	(NA)
Type of Report:	NBC 3 (Nuclear)
D.	D. DD 2115Z
F.	F. NH267856 estimated
Y.	Y. 01030143 degrees
Z.	Z. 02001403

NOTE: An NBC 3 (Nuclear) report is in fact prepared at the NBCE of division or higher headquarters; you in reality would not be preparing such a report except to provide a quick means of giving information to your next higher headquarters. Your medical unit would receive an NBC 3 (Nuclear) report from the NBCE, from which you would prepare a detailed fallout prediction (when constructed on your map, a simplified and detailed would look much the same). The purpose of the requirement of preparing an NBC 3 (Nuclear) report is to correlate the information contained in such a report with that which can be determined from an NBC 1 (Nuclear) report and an Effective Downwind Message.

d. Prepare a simplified fallout prediction from the above information.

The solution of this requirement can be seen when you trace the steps in the construction of the fallout prediction on the overlay, as described in Appendix A, GR 76-332-100, p. A-31. Ground zero can be estimated with the information furnished by the Commanding Officer of the 98th CSH who was located at the Division Engineer Battalion at the time of the nuclear detonation. From his position (313817), the observed mushroom stem was to the NW at 312° Mag. as determined by a compass reading, and a flash-to-bang time was about 18 seconds; with this information, draw a line from the CO's position at an angle of 320° grid (312° Mag. + 8° = 320° grid) and with a length of 6 km. The flash-to-bang time of 18 seconds gives a distance to the point of burst of approximately 6 km (from the speed of sound being approximately 330 meters per second). From this approximate position, we can see that it falls almost in the center of the 3d Bde, 36th Inf Div.

With the arrival of information from the Commanding Officer, 98th CSH that the type detonation is, in fact, a surface burst, the necessity of a simplified fallout prediction is established. First, the approximate GZ (267856) is located on the map (6 km from 313817) at grid azimuth 320° with the location of GZ and an Effective Downwind Message, a simplified fallout prediction can be prepared. From the Charlie line (for a 10 KT weapon) of the Effective Downwind Message, the data given is 123020. From GZ draw a reference line at 123° (123030) from GN; then, construct right and left radial lines at 20° from the reference line. From page A-37 of Appendix A, GR 76-332-100, a cloud radius of about 2.3 km is found for a 10 KT weapon. For immediate consideration increase 2.3 km to 3 km. Draw a circle of 3.0 km radius representing the cloud radius with GZ as its center. Then using GZ as center and a radius of 14 (from 02001403) an arc is drawn so that it intersects the left and right radial lines. Tangents to the circle of 3.0 km

radius are drawn from the intersections of the radial lines and the 14 km arc. Zone I is the area formed by these tangents and the 14 km arc. Zone II is found by doubling the 14 km distance and describing a second arc of 28 km radius with center at GZ. Zone II is the area bounded by the first and second arcs and the portions of the radial lines extending from the points of intersections of the tangents with the 14 km arc.

5–15. SPECIAL SITUATION CONTINUED

It is now 1530 hrs, this date. The following message from the S3 Med Bn is received by your unit over the field phone:

Immediate
DD 2125Z
Unclassified
Hq, 36th Inf Div
All subordinate Hq, this Cmd
NBC 3 (Nuclear) Report
D. DD2115Z
F. NH267856 actual
Y. 01030143 degrees
Z. 02001403

5–16. THIRD REQUIREMENT

a. Does the above NBC 3 (Nuclear) Report agree with your fallout prediction using the NBC 1 (Nuclear) report and the Effective Downwind Message?

Yes.

b. Is your unit in the path of fallout? Which zone, if any?

Yes. Zone I.

c. What is the military significance of:

Zone I? Zone II? Areas outside Zone I or II?

(1) Zone I: Zone of Immediate Operational Concern—zone within which there will be areas where exposed, unprotected personnel may receive doses of 150 rad or greater, in relatively short periods of time (less than four hours after actual arrival of fallout).

(2) Zone II: Zone of Secondary Hazard—zone within which total dose to exposed, unprotected personnel is not expected to reach 150 rad within a period of a 4 hours after arrival of fallout, but within which personnel may receive a total dose of 50 rad or greater within the first 24 hours after the arrival of fallout.

(3) Outside the Predicted Area--exposed, unprotected personnel may receive a total dose that does not exceed 50 rad in the first 24 hours after actual arrival of fallout. The total dose for an infinite stay should not be greater than 150 rad.

d. Does the fallout prediction mean that the 98th CSH definitely will or will not receive radiological fallout in the amounts stated above for each zone? Why?

No, it is a prediction which means that it may or may not occur. It does not state that it will absolutely occur.

e. What is the predicted arrival time of radiological fallout at the 98th CSH?

Forty-two (42) min after the nuclear detonation or about 1557 hrs, this date. The 98th CSH is approximately 14 km from GZ. From the Charlie line of the Effective Downwind Message the cloud speed is 20 km per hr (60 min).

$$\frac{20 \text{ km}}{14 \text{ km}} = \frac{60 \text{ min}}{X \text{ min}}$$

$$20x = 840$$

$$x = 42 = \text{Estimated time of arrival}$$

As the nuclear detonation occurred 1515 hrs, this date, this time plus the 42 min arrival time means that the predicted arrival time of the radiological fallout would be approximately 1557 hrs, this date (CST).

f. In an evaluation of the situation, what considerations should be made as to your unit staying in or moving from its present location?

(1) Mission of the 98th CSH.

(2) Knowledge of where the radilogical fallout definitely will not fall. This means that any reasonable area to which you could relocate the unit may be as bad or worse than your present position in regard to the hazards and/or dose rates of the fallout.

(3) Required permission to relocate the 98th CSH as determined by the Med Group Commander.

(4) Time required by the 98th CSH to move to a new location. It will take time to prepare for a hospital to move to a new location. Naturally the farther away the new position would be, the longer the transit time.

(5) Availability of adequate shelters nearby.

g. Of the possibilities for action remaining after the considerations in f above, what course of action would you take?

Of the possibilities for action, the logical course of action to follow, considering the time available, would be an attempt to take shelter in your local area. Shelter facilities available in your area are (1) foxholes for perimeter guards and perhaps some additional personnel in the tent area of the 98th CSH and (2) the shelter provided by the farmhouse cellar and root cellar. The action required on your part would be to order "Prepare for fallout." As the time is now 1530 hrs, this date, and the expected arrival time of the radiological fallout is 1557 hrs, there remains only approximately 27 min prior to arrival of fallout in order to close into the various shelter facilities.

5–17. SPECIAL SITUATION CONTINUED

The CO of the 98th CSH returned to the unit at 1534 hrs, this date. He has decided to follow your recommendation to make use of the cellar of the nearby old house as a fallout shelter for unit personnel and patients. The root cellar is to be used for the headquarters section of the CSH. It is now 1535 hrs, this date.

5–18. FOURTH REQUIREMENT

a. How will the above actions affect the unit's mission? Why?

Moving to shelters will reduce the ability of the 98th CSH to perform its mission by hampering mobility of personnel within the unit and by reducing facilities available to the unit. In addition, new urgent requirements will occur due to the certainly less than optimum shelter facilities.

b. What preparations should have been made for occupancy of the shelters?

Readily available food, water, and lighting. Continued communication with the Med Bn switchboard. Any additional efforts to increase the protection factor of the shelters available; for example, digging deeper and providing top cover to foxholes and sandbagging the first floor above the farmhouse cellar. Also, considerations must be given for a continuation of the medical mission within the cellar shelter area.

c. What time remains before the predicted onset of fallout?

About 22 min. As the expected arrival time of the radiological fallout is 1557 hrs, this date and the present time is now 1535 hrs, approximately 22 min remain before the onset of radiological fallouts.

d. Comment on the fact that sufficient time may not remain to have all unit personnel take to the shelters.

Do your best! It is quite imperative that all personnel take some type of protective action in the shelter facilities available. Space in the farmhouse or root cellar may not be available to all personnel. Some personnel in addition to the perimeter guards may have to take shelter in foxholes.

e. Have all the unit personnel been ordered to the farmhouse shelters? Why?

No. Some personnel are required as perimeter guards around the tent area.

f. Has coordination concerning the movement to shelters been made with other headquarters? Which ones?

The following units should be informed of your relocation to the shelter area due to the radiological fallout: supported medical battalion, supporting evacuation hospital, and the parent medical group.

g. What do you expect the TF for the cellars to be? The PF?

TF for this type of shelter is 0.1; the PF (being the reciprocal of the TF) is 10. This information is provided in Appendix A, GR 76-332-100, pages A-2 and A-3.

h. How much would one layer of sandbags about 6.6 inches thick on the floor above the house cellar reduce the radiation exposure from overhead? Why?

The two half-value layer thicknesses of earth in sandbags would reduce the overhead radiation to one-fourth (1/2 x 1/2 = 1/4) or 25%; however, this reduction applies only to that radiation which comes into the shelter from overhead and cannot be applied to the estimated TF across the board. The best you can say is that it will help, but you cannot quantify your estimate. Ref: Appendix A, GR 76-332-100, page A-5.

5-19. SPECIAL SITUATION CONTINUED

You are still the medical operations assistant. At 1600 hrs, this date, one of unit's monitors reports 1 rad/hr. At 1608 hrs, this date, the same monitor reports an outside dose rate of 5 rad/hr. During the stay in the farmhouse cellar shelter, the following readings on your radiac instrument are observed:

Time	Time after Detonation	Inside Dose rate (rad/hr)	Outside Dose rate (rad/hr)
1600	H + 45 min	–	1.0
1605		–	5.0
1610		–	15.0

1620		5.0	100.
1640		7.5	
1650		8.7	
1700		10.5	
1715	H + 2	10.0	
1730		9.0	
1745		7.7	
1800		7.0	
1900		4.5	
2000		3.5	
2100		2.7	
2200		2.6	
2300		2.0	
2400		1.7	
Next Day			
0300		1.3	
0600		0.8	
0900		0.7	
1200		0.6	

At 1620 hrs, you order a monitor outside the house/cellar shelter to take an outside dose rate reading which he reports as 100 rad/hr. His stay time was 5 minutes.

5-20. FIFTH REQUIREMENT

a. What actions do you have the unit personnel take upon being informed that 1 rad/hr has occurred? Take such action!

(1) Order all personnel into or see that all personnel have entered the shelters. A "contact report" (NBC 4), using IMMEDIATE precedence is submitted whenever an initial ground dose rate of 1 rad/hr or more is detected in an area within the predicted fallout area.

(2) IMMEDIATE
DD 2208Z
Unclassified
98th CSH
HQ, 36th Inf Div (NBCE) thru Med Bn
NBC 4 (Nuclear)
Q.NH 361758
R.1 (initial)
S.DD2200Z

b. How was the monitor instructed to take his outside reading? What radiac instrument should he have used?

By holding the IM-174A/PD waist-high or 1 meter above the ground while 10 meters away from any structure and rotating in a 360 degree circle. The monitor reports the highest dose rate reading?

c. What is the actual PF of the shelter in the cellar of the house?

Twenty. This is determined by an outside dose rate reading by the monitor at 1620 hrs, this date of 100 rad/hr. At the same time, or shortly thereafter, an inside dose rate of 5 rad/hr was determined. As the PF equals the outside dose rate divided by the inside dose rate (100 rad/hr divided by 5 rad/hr), the overall PF for the house celler shelter is 20. As would be expected, the calculated or actual PF is somewhat different than the stated PF in the reference material since the actual PF would be dependent upon composition of cellar wall, thickness of the cellar wall, composition of the surrounding soil, depth within the ground of the cellar and composition of overhead ceiling material. In this particular case, the overall protection factor within the cellar shelter is greater than 10. But because the overhead two HVL's of earth of the ceiling of the cellar does not shield against all radiation entering the shelter, the rated overall protection factor of the cellar is not increased by a factor of 4. This can be seen from the actual exposure rate determination of the shelter which is PF = 20 rather than PF = 40 as might be expected from a shelter with an original PF = 10 and then 2 HVL's of shielding added.

d. Would you report the above experienced dose rates to any other units? Which?

Yes, to the Div NBCE through the Med Bn and also to the Med Gp headquarters.

e. What message form would you use?

NBC 4 (Nuclear) Report. Ref: Appendix A, GR 76-332-100, page A-7.

f. How would you determine if the radiological fallout follows "standard decay ?"

By the ABC-M1 Calculator. As the decay rate on the ABC-M1 Calculator is based on the standard decay rate, if the decay rate is faster or slower than the decay rate given on the ABC-M1 Calculator, it is non-standard. The radiological contamination in this situation is following a standard decay rate.

g. Has the peak dose rate occurred? At what time? What is the significance of this?

Yes, at 1700 hrs, this date. The significance of this is that decay calculations can now be made with the ABC-M1 Calculator or nomograms.

h. How long would it be necessary to remain in the shelters for the occupants to obtain a dose of 25 rad? (Assume 7 rad dose up to H + 2 hours.)

About 4 hrs. First subtract 7 rad, the quantity of radiation the occupants of the shelter have received up to H + 2 hrs, from the total overall dose of concern for the occupants which is 25 rad; thus 18 rad will remain for the shelterees to receive after H + 2 hrs. Then on the ABC-M1 Calculator set the inside shelter dose rate of 10- rad/hr on the outer dial in line with the corresponding time of interest on the middle dial which is H + 2 hrs. Set the

inner dial to H + 2 hrs for the time of entry. Locate on the outer dial a total dose of 18 rad; following the guide line down to the inner dial which should read about H + 6 hrs and subtracting H + 2 from H + 6 hrs, this leaves 4 hrs stay time in order to receive the 18 rad which with the 7 rad up to H + 2 gives a total dose of 25 rad. (Ref: Subcourse, para 3-9).

i. How long do you anticipate you must remain in the shelters from H + 2 hrs until the outside dose rate decays to the command operational level? (4 rad/hr.) What will be the total dose to the shelter occupants in that time?

(1) The first consideration given to this question is what is a or the outside normal operational radiation dose rate level? This will not be determined by an individual unit but a command SOP based upon comparison of the risk due to a particular dose rate of radiation and the necessity to accomplish the tactical mission. Such a decision will be a command decision based upon willingness to receive resulting biological hazards of the selected dose rate as evaluated by the major command surgeon. The normal operational dose rate levels to nuclear radiation may very well vary within a major command dependent upon the various tactical requirements. It is naturally assumed that such operational levels have been established heretofore in SOP's and in contingency plans.

(2) In this particular problem Hq, IX Corps has established as its acceptable normal operational dose rate level for units in a defensive position to be 4 rad/hr (Ref: Subcourse, para 5-11). By knowing that a H + 2 hrs (1715 hrs, this date) the inside dose rate is 10 rad/hr and with a protection factor for the shelter of 20, the outside dose rate is calculated to be 200 rad/hr. Then by using the Radiac Calculator, ABC-M1, setting the middle dial at H + 2 with the 200 rad/hr located on the outer dial, the dose rate occurring due to standard decay can be determined for any period of time. By following the dose rate on the outer dial down to 4 rad/hr and reading the time at which this will occur on the middle dial, it is determined that an outside dose rate of 4 rad/hr will occur at approximately H + 2 days plus 4 hrs or H + 52 hrs. (Ref: Subcourse, para 3-9).

(3) To determine what the total dose is to the shelter occupants in that period of time, the inside dose rate must first be determined; the inside dose rate at H + 2 hrs is 10 rad/hr on the outer dial. By aligning the middle dial of the calculator at H + 2 hrs with 10 rad/hr on the outer dial, the inside dose rate based upon the standard decay of the outside radiological fallout can be determined. Next align the 2 hr mark of the inner dial with the time of entry mark on the middle dial. By observing the location of the 2-day plus 4 hr mark on the inner dial (about the left third of the red band) and following this mark to the outer dial, a dose of approximately 46 rad is determined. Thus, approximately 46 rad will be the dose of the shelterees during their stay for the period from H + 2 hrs to H + 52 hrs. To determine their dose for the total length of stay in the shelter, add the 7 rad received prior to H + 2 hrs to that 46 rad received after H + 2 hrs; thus, a total dose of 53 rad will be received by the shelterees at H + 54 hrs. (Ref: para 3-9).

j. What is the dose rate to those personnel in house cellar shelter at 1715 hrs? What is the dose rate in foxholes around the tent area at 1715 hours, this date? How could the perimeter guards reduce this dose rate?

(1) Ten (10) rad/hr as determined by inside monitoring.

(2) As the outside dose rate at H + 2 hrs is 200 rad/hr and the TF of a foxhole is 0.1, the dose rate to those personnel in foxholes at the tent area is 20 rad/hr. (200 X 0.1) Ref: Appendix A, GR 76-332-100, page A-3.

(3) The perimeter guards in foxholes could reduce this dose rate by digging deeper or providing some type of top cover. This could increase the protection factor to approximately 20 thereby reducing the dose rate at H + 2 hrs to 10 rad/hr. (PF = 20; TF = 10/200 = .05; 200 x .-05 = 10 rad/hr).

k. Five ambulatory casualties have been directed by a perimeter guard at the tent area to the house cellar shelter and arrive there at 0915 hrs, next day (H + 18 hrs). Do you admit them? As a result of your decision, what actions are taken concerning the casualties? Why?

Yes, you would admit them to your shelter after they have been decontaminated. Of concern here is implementing all the precautionary measures possible to minimize exposure and contamination inside the shelter. At H + 18 hrs it will be noted that the dose rate inside the shelter is approximately 0.7 rad/hr, which is greater than the maximum range of the AN/PDR-27, thereby nullifying its usefulness in these conditions. It would be logical to assume that these individuals traveling in the fallout field which is still emitting approximately 14 rad/hr would be contaminated from such radiological contaminants as acquired in the immediate area of this fallout field. Because of this and attempts to reduce contamination as much as possible, these persons now should remove, shake and/or brush outer garments to remove the gross contamination. Of course, this procedure would be performed outside the shelter area. Should assistance be needed by these individuals to accomplish this decontamination, selected shelterees would be sent outside the shelter to assist them. It is somewhat needless to say that any or all procedures needed to save any of the lives of the casualties would be performed prior to the precautionary decontamination procedures. In an attempt to determine total dose of radiation to these individuals, the IM-93 should be checked, if available.

5-21. SPECIAL SITUATION CONTINUED

It is now 1515 hrs, next day (H + 24 hrs). As some shortage of food and water has occurred, you order two persons to obtain more C rations and water from the tent area. They return with ten 5-gallon water cans and three boxes of C rations. You assume all containers are radiologically contaminated.

5-22. SIXTH REQUIREMENT

a. Do you recommend to CO that the food and water be used? Why? Of consideration here is the amount of contamination on the food and in the water

compared to the necessity of the shelterees to consume the food and water. It would be logical to assume that the C ration boxes would contain only outer contamination in which case the outer boxes should be cleaned or removed with caution to minimize contamination to the inner boxes. All of the radiological fallout at this time would be on the ground; therefore, such decontamination procedures to the C ration boxes should be performed outside the shelter with care being taken that after the inner boxes are removed they do not come in contact with the ground or surrounding surface radiological contaminants. In a similar fashion the 5-gallon water cans could be easily decontaminated assuming that these cans were filled in the old tent area prior to onset of fallout. Thus, the cans could be washed or dusted off before being taken into the shelter. Should such water cans be required to be filled from the water trailer still in the old tent area, such minuscule amounts of contaminants as may inadvertently gain entry into the water cans during their filling from the water trailer would be insignificant in relationship to the possible physiological hazards resulting to the shelterees from lack of water. In bringing anything into the shelter from the outside area, it would be logical to assume that it is radiologically contaminated and therefore should be decontaminated.

b. Do you have the containers decontaminated before bringing them into the shelter area? Why? How?

Yes, as stated in paragraph above.

c. If they returned at 1545 hrs, what dose would you expect them to receive? Why?

Approximately 5 rad. Practically, this dose determination would be made by the IM-93 carried by the personnel. Using the Radiac Calculator ABC-M1 and aligning H + 2 hrs on the middle dial with 200 rad/hr, one can determine that at H + 1 day the outside dose rate would be 10 rad/hr. As the personnel had an outside exposure for half an hour their dose would be 5 rad. ($\frac{30}{60} \times 10 = 5$.)

d. Would you keep a record or log of the doses of personnel in the shelters? Why?

Yes. Records as complete as practical should be maintained for all known exposure to the shelterees. Such records would then be of benefit in future evaluation of patients due to the possible complications in their recovery due to irradiation. Such records also provide information as to those individuals with minimum doses in case of the need of special tasks outside the shelter where they would receive additional outside exposure. The consideration here is to spread the radiation doses equally among selected shelter personnel so that the hazard of radiation to any one or few individuals is minimized.

e. Would you report to any other units your dose rate levels during this time? Which units? What form?

Yes, the Division NBCE through the Med Bn via an NBC 4 (Nuclear) Report, and the parent medical group. Reporting interval would be specified in local SOP.

5–23. SPECIAL SITUATION CONTINUED

It is now 1900 hrs, two days later (approx H + 52 hrs). The outside dose rate is 4 rad/hr which has been determined by IX Corps as an acceptable operational level.

5–24. SEVENTH REQUIREMENT

a. What actions would you recommend to the CO to have the hospital become fully operational in the tent area?

(1) As radiological contamination is spread throughout the tent area, occupation of the tent area would require extensive decontamination to minimize and decrease the hazards from this remaining 4 rad/hr. Such actions would include shaking the tops of tents, brushing the tops and sides of tents and brushing and removing contaminants from items left in the open during the fallout; removing a small top layer of earth immediately around the tent area, say approximately 10m distance from any occupied location, and decontamination of vehicles, preferably at some other areas and with water. The tent area itself should be decontaminated preferably by dry methods.

(2) Movement of unit to less contaminated area after maximum amount of decontamination has been accomplished in the contaminated area prior to movement to clean area. This would include requesting assistance from the engineer battalion and any available decontamination teams within the division area.

b. If the fallout had followed closely the predicted area what actions would you recommend to the CO at this time, and if concurrence is obtained, what actions would you take to implement such action? Explain.

Recommend movement to support command area which is not within the fallout area. It will be recalled that this was the purpose of the CO's liaison visit to the division surgeon prior to the nuclear detonation. Naturally, request for such movement to new location would be coordinated through the Med Bn and Med Gp. Attempts to decontaminate and minimize contained radiological contaminants within unit equipment prior to relocation in new position should be effected as cited in paragraph a above. Patients on hand should be evacuated prior to unit move.

EXERCISES, LESSON 5

REQUIREMENT. The following exercises are to be answered by marking the lettered response that best answers the question; or by completing the incomplete statement; or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solution to Exercises" at the end of the lesson, and check your answers with the solutions.

1. After a nuclear attack, which of the following sources of water is the LEAST safe?

a. Water in canteens and water cans.

b. Water from wells and springs.

c. Water from streams.

d. Water from lakes and ponds.

2. Medical personnel and medical units generally will be faced with two primary problems when operating in a significant local fallout situation:

a. Construction of shelters and evacuation of patients.

b. Unit survival and performance of mission.

c. Dispersion of unit and evaluation of hazards.

d. Rotation of exposed personnel and evaluation of hazards.

3. What is the most desirable method for the decontamination of vehicles?

a. Aging.

b. Brushing.

c. Washing with water and detergents.

d. Washing with steam.

e. Scrubbing with strong caustic solutions.

4. In addition to surface winds, the direction of fallout from ground zero is based upon:

a. Height of burst.

b. Yield of burst.

c. Winds aloft.

d. Ambient temperatures.

5. It is now 1000 hours, San Antonio time. What time is it, Greenwich Mean Time?

a. 0800 hours.

b. 1000 hours.

c. 1600 hours.

d. None of the above.

6. The line in the Effective Wind Message which gives the day and time at which the winds were measured is:

a. Alfa.

b. Bravo.

c. Charlie.

d. Zulu.

7. Letter item J of the NBC 1 report is the:

a. Developing cloud.

b. Flash-to-bang time.

c. Ground zero.

d. Wind direction.

8. The table on page A-37 of Appendix A, GR 76-332-100 gives a cloud radius of about _____ km for a 100 KT nuclear weapon.

a. 12.

b. 8.1.

c. 6.7.

d. 3.8.

9. If the outside dose rate of residual radiation is 100 rad/hr, the dose rate in a foxhole is _____ rad/hr.

a. 100.

b. 10.

c. 1.

d. .05.

10. As shown on the map and overlay, the 98th CSH is in Zone I. Which of the following would represent a location for the hospital which would be outside Zone I and Zone II?

a. 366755.

b. 352751.

c. 350735.

d. 380792.

11. As shown on the map and overlay, what is the location of the nearest unit to ground zero of the nuclear detonation?

a. 273861.

b. 361758.

c. 313457.

d. 272823.

12. An illumination time of 10 seconds would indicate an approximate yield of _____ KT.

a. 125.

b. 160.

c. 200.

d. 250.

13. What is the downwind distance in kilometers of Zone I for a 100 KT weapon with an effective wind speed of 30 kmph?

a. 20.

b. 30.

c. 40.

d. 50.

14. Which NBC (Nuclear) report would you use for immediate warning of expected contamination from a nuclear detonation?

a. NBC 1 (Nuclear) report.

b. NBC 2 (Nuclear) report.

c. NBC 3 (Nuclear) report.

d. NBC 5 (Nuclear) report.

15. Which of the following represents the distance from 36th Div Hq to GZ on the overlay?

a. 3.4 km.

b. 6 km.

c. 12 km.

d. 13 km.

16. Which of the following represents the correct formula for a transmission factor?

a. $TF = \frac{ID}{OD}$

b. $TF = \frac{OD}{ID}$

c. $TF = OD \times ID$

d. $TF = \frac{OD \times ID}{2}$

17. In the effective wind message, what stands for the wind speed to the nearest kilometer per hour?

a. sss.

b. ttt.

c. DD.

d. ddd.

SOLUTIONS TO EXERCISES, LESSON 5

1. d (para 5–3a)
2. b (para 5–2a, b)
3. a (para 5–3c(2))
4. c (para 5–5)
5. c (para 5–13a)
6. d (Appendix A, p A–6 thru 8)
7. b (Appendix A, p A–6 thru 8)
8. c (Appendix A, p A–37)
9. b (Appendix A, A–3)
10. c (Map and overlay)
11. a (Map and overlay)
12. d (Appendix A, p A–33)
13. c (Appendix A, p A–36)
14. c (Appendix A, p A–6 thru 8)
15. a (Map and overlay)
16. a (para 5–6c)
17. a (para 5–8d(3)(b))

ACADEMY OF HEALTH SCIENCES
PREVENTIVE MEDICINE DIVISION
NUCLEAR, BIOLOGICAL, CHEMICAL SCIENCES BRANCH

APPENDIX A GENERAL REFERENCE

ON

THE EFFECTS OF NUCLEAR, BIOLOGICAL AND CHEMICAL WEAPONS

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Dose (Range)		0-100 cGy (subclinical range)	100-800 cGy (sublethal range)			Over 800 cGy (lethal range)	
			100-200 cGy	200-600 cGy	600-800 cGy	800-3000 cGy	over 3000 cGy
INITIAL PHASE	Incidence of nausea & vomiting	NONE	5–50%	50–100%	75–100%	100%	
	Time of onset	.....	Approx. 3–6 hrs.	Approx. 2–4 hrs.	Approx 1–2 hrs.	Less than 1 hr	
	Duration	.....	Less than 24 hrs.	Less than 24 hrs.	Less than 48 hrs.	Less than 48 hrs.	Approx 48 hrs.
	Combat effectiveness	100%	100%	Can perform routine tasks. Sustained combat or comparable activities hampered for 6–20 hrs.	Can perform only simple routine tasks. Significant incapacitation in upper part of range. Lasts more than 24 hrs.	Progressive incapacitation following an early capability for intermittent heroic response.	Progressive incapacitation following an early capability for intermittent heroic response.
LATENT PHASE	Duration	.....	More than 2 weeks.	Approx. 7–15 days.	None to approx 7 days	None to approx 2 days	NONE
SECONDARY PHASE	Signs & symptoms	NONE	Moderate leukopenia.	Severe leukopenia; purpura, hemorrhage; Infection; epilation about 300 rads.		Diarrhea; fever; disturbance of electrolyte balance	Convulsions; tremor; ataxia; lethargy
	Time of onset post exposure.	.....	2 weeks or more.	Several days to 2 weeks		2–3 days	
	Critical period post exposure.	.....	NONE	4–6 weeks		5–14 days	1–48 hrs
	Organ system responsible.	NONE		Hematopoietic tissue		Gastrointestinal tract	Central nervous system
HOSPITALIZATION	Percentage	NONE	Less than 5%	90%	100%	100%	100%
	Duration		45–60 days	60–90 days	90–120 days	2 weeks	2 days
INCIDENCE OF DEATH		NONE	NONE	0–80%	90–100%	90–100%	
AVERAGE TIME OF DEATH			.....	3 weeks to 2 months		1–2 weeks	2 days
THERAPY		NONE	Reassurance hematologic surveillance	Blood transfusion, antibiotics		Maintenance of electrolyte balance.	Sedatives

Radiation dose effect relationship.

CORRELATION FACTORS FOR RESIDUAL RADIATION
(REF: GTA 3-6-3)

ENVIRONMENTAL SHIELDING	LOCATION OF SURVEY METER	CORRELATION FACTOR
VEHICLES		
M1 Tank		20
M60 Tank	Turret, rear top	25
	Turret, front	53
	Chassis, near driver	23
M2 IFV		9.1
M3 CFV		9.1
M113 APC	Directly in front of driver on front wall	3.6
	Near first squad member on left facing forward	3.6
M109 SP howitzer	Near driver, left side	3.5
	Rear, right side	3.4
M88 Recovery vehicle	Commander position	6.9
M577 Command post carrier	Near driver, right side	3.2
	Rear, left side	2.5
M551 Armored recon abn assault vehicle	Near driver, right side	4.6
TRUCKS		
1/4-ton		1.3
3/4-ton		1.7
2-1/2-ton		1.7
4-ton to 7-ton		2
STRUCTURES		
Multi-story building		
Top floor		100
Lower floor		10
Frame house First floor		2
Basement		10
UNDERGROUND SHELTER (3-foot earth cover) 5,000		
FOXHOLES		10

TRANSMISSION & PROTECTION FACTORS FOR RESIDUAL RADIATION
(REF: GTA 3-6-3)

TF = IN / OUT	IN = TF X OUT	OUT = IN / TF
PF = OUT / IN	IN = OUT / PF	OUT = PF X IN

ENVIRONMENTAL SHIELDING	TRANSMISSION FACTOR (TF)	PROTECTION FACTOR (PF)
VEHICLES		
M1 Tank	0.04	25
M60 Tank	0.2	25
M2 IFV	0.2	5
M3 CFV	0.2	5
M113 APC	0.3	3.3
M109 SP howitzer	0.2	5
M548 Cargo vehicle	0.7	1.4
M88 Recovery vehicle	0.09	11 M577 Command post carrier 0.3 3.3
M551 Armored recon abn assault vehicle	0.2	5
M728 Combat engr vehicle	0.4	20
TRUCKS		
1/4-ton	0.8	1.3
3/4-ton	0.6	1.7
2-1/2-ton	0.6	1.7
4-ton to 7-ton	0.5	2
STRUCTURES		
Multi-story building		
Top floor	0.01	100
Lower floor	0.1	10
Frame house		
First floor	0.6	1.7
Basement	0.1	10
URBAN AREA (in open)	0.7	1.4
WOODS	0.8	1.3
UNDERGROUND SHELTER (3-foot earth cover)	0.0002	5000
FOXHOLES	0.1	10

RULES OF THUMB – RESIDUAL RADIATION – DOSE AND DOSE RATE ESTIMATION
(REF: TM 8–215, p 39)

1. The "Seven-Ten" Rule

   a. Used only for dose rate estimations.

   b. For every sevenfold increase in time, the dose rate is divided by 10.

   c. Examples:

      (1) R_1 = 1,000 rad/hr; R_7 = 100 rad/hr; R_{49} = 10 rad/hr; R_{343} = 1 rad/hr.

      (2) R_3 = 50 rad/hr; RF_{21} = 5 rad/hr.

   d. This rule also works in reverse—R_{28} = 15 rad/hr; R_4 = 150 rad/hr.

2. The "Double-The-Time" Rule.

   a. Used only for dose rate estimations.

   b. When time is doubled, the new dose rate may be found by dividing the old dose rate by two and subtracting ten percent of the result.

   c. Examples:

      (1) If the dose rate at H+1 (R_1) is 1,000 rad/hr, what will be the dose rate at H+2 (R_2)?

      ANS: $\frac{1,000}{2} = 500$

      10% of 500 = 50

      500 – 50 = 450 rad/hr at H+2

      (2) If the dose rate at H+1 is 1,000 rad/hr, what will be the dose rate at H+4 (R_4)?

      ANS: Two twofold increases in time are involved. Dose rate at H+2 is 450 rad/hr (see 1 above).

      $\frac{450}{2} = 225$

      10% of 225 = 23

      225–23 = 202 rad/hr at H+4

      (3) Working the rule in reverse is not algebraically correct.

3. The "Fit Forever" Rule

a. Used only for total dose

b. The rule is based on the formula D = F x I x T where

(1) D = The total dose which would be received by an individual who stays forever at a location in a fallout area

(2) F = A constant, five

(3) I = The intensity or dose rate at that location at the time the exposure began.

(4) T = The time in hours after the burst that the exposure began.

c. Example—if an individual entered a fallout a ea at H+4 and the intensity at that location and at that time was 20 rad/hr, what total dose would he receive if he remained there indefinitely (forever)?

D = F x I x T = 5 x 20 x 4 = 400 rad total dose

HALF-VALUE LAYER THICKNESS OF COMMON MATERIALS
FOR FALLOUT RADIATION
(Ref: TM 8.215, Table 13)

STEEL	1.8 cm	0.7 in
CONCRETE	5.6 cm	2.2 in
EARTH	8.4 cm	3.3 in
WATER	12.2 cm	4.8 in
WOOD	22.4 cm	8.8 in

RADIATION SHIELDING EQUATION

$R_i = R_o / 2^n$ or $R_o = R_i \times 2^n$

R_i = Inside Radiation Dose Rate

R_o = Outside Radiation Dose Rate

n = Number of Half-Value Layers

NBC WARNING AND REPORTING SYSTEM
(Ref: FM 3-3 w/ch 1)

NBC 1 (OBSERVE"S REPORT)

LINE	NUCLEAR	CHEMICAL	BIOLOGICAL
B	NB062634	LB200300	LB200630
C	90 Deg Grid		
D	201405Z	201405Z	200410Z
E		201412Z	200414Z
F		LB206300 Est	LB206300 Act
G	Aircraft	Bomblets	Aerial Spray
H	Surface	Nerve, V, Air Burst	Unknown
J	60 sec.		
L	15 Deg		
M			

NOTE: Line items B, D, H, and either C or F should always be reported; other line items may be used if the information is known.

NBC 2 REPORT (EVALUATED DATA)

LINE	NUCLEAR	CHEMICAL	BIOLOGICAL
A	A024	B002	C001
D	201405Z	200945Z	201395Z
F	LB187486 Act	LB126456 Act	LB206300 Act
G	Aircraft	Bomblets	Unknown
H	Surface	Nerve V. Air Burst	Unknown
N	50		
Y		0270 Deg, 015 km/h	0270 deg, 015 km/h
ZA		518640	518640

NOTES:
1. This report is normally based on two or more NBC 1 reports. It includes an attack location and, in the case of a nuclear detonation, an evaluated yield.
2. Refer to the chemical downwind message to determine could cover, significant weather phenomena, and air stability.
3. Lines that are filled in are necessary for report (or if you know that information you must fill it in).

NBC 3 REPORT (IMMEDIATE WARNING OF EXPECTED CONTAMINATION)

LINE	NUCLEAR	CHEMICAL
A	A024	B002
D	201405Z	201415Z
F	LB187486 Est	LB560750 Act
H		Nerve, V, Air Burst
N	50	
PA		LB556751
		LB559754
		LB632774
		LB610794
		LB 58747
PB		In attack area 2–4 days
		In hazard area 1–2 days
Y	02720312	0270 Deg, 015 km/h
Z	01902505	
ZA		518640
ZI	010, 0017, 0028, 007	

NOTES:
1. If the effective windspeed is less than 8 km/h, line Z of the NBC 3 (nuclear) consists of three digits for the radius of Zone I.
2. If the windspeed is less than 10 km/h, line PA of the NBC 3 (chemical) is 010, which is the radius of the hazard area.
3. Line ZI is used only for NUCWARN reports. When line ZI is used, line Z is not used.
4. Line A,D,F,Y, and Z must be completed for Nuclear and A,D,F,H, PA.PB (if ground contamination is present)m y, and Z for chemical.

NBC 4 REPORT (RECONNAISSANCE, MONITORING, AND SURVEY RESULTS)

LINE	NUCLEAR	CHEMICAL
H		Nerve, V
Q	LB123987	LB200300, Liquid
R	35	
S	201535Z	170610Z

NOTES:
1. Line items H, Q, R, and S may be repeated as often as necessary.
2. Radiation dose rates are measured in the open, with the instrument 1 meter above the ground.
3. In line R, descriptive words such as "initial," "peak," "increasing," "decreasing," "special," "series," "verification," or "summary" may be added,
4. H.Q. and S are mandatory for chemical and Q.R. and S for nuclear.

NBC 5 REPORT (AREAS OF ACTUAL CONTAMINATION)

LINE	NUCLEAR	CHEMICAL
A	A0012	B005
D	200700Z	200700Z
F		
H		Nerve, V, Air Burst
O		
R		
S		201005Z
T	201505Z	201110Z
U		
V	ND651445	
	ND810510	
	ND821459	
	ND651455	
W	ND604718	
	ND991 86	
	ND114420	
	ND595007	
X		ND206991
		ND201576
		ND200787
		ND206991

NOTE: 1. This report is best sent as an overlay if time and the tactical situation permits.
2. Lines A,D,F,T or O,R,U,V,W, and X are reported for Rad contaminator and A.D.H.S.T. and X for Chem Bio.

NBC 6 REPORT (DETAILED INFORMATION ON CHEMICAL OR BIOLOGICAL ATTACKS)

LINE	CHEMICAL OR BIOLOGICAL
A	B001
D	200945Z (May)
E	200950Z (May)
F	LB200300, Act
G	Artillery
H	Nerve, v, Air Burst
I	20 rounds
K	Mostly small houses and barns, elevation 600 meters
M	Attack received as counterfire, enemy bypassed on right flank of attack area
Q	Liquid ground sample taken by detection team in attack area
S	201005Z (May)
T	201110Z (May)
X	As per overlay
Y	Downwind direction 0090 degrees, windspeed 010 km/h
ZB	This is the only chemical attack to in our area to date

NOTES: 1. This report is submitted only when requested.
2. This report is completed by battalion and higher NBC personnel. It is in narrative form, giving as much detailed information as possible for each line item.

MEANING OF LINE ITEMS IN NBC REPORTS
(Ref: FM 3-3 w/ch 1, Table 2-1)

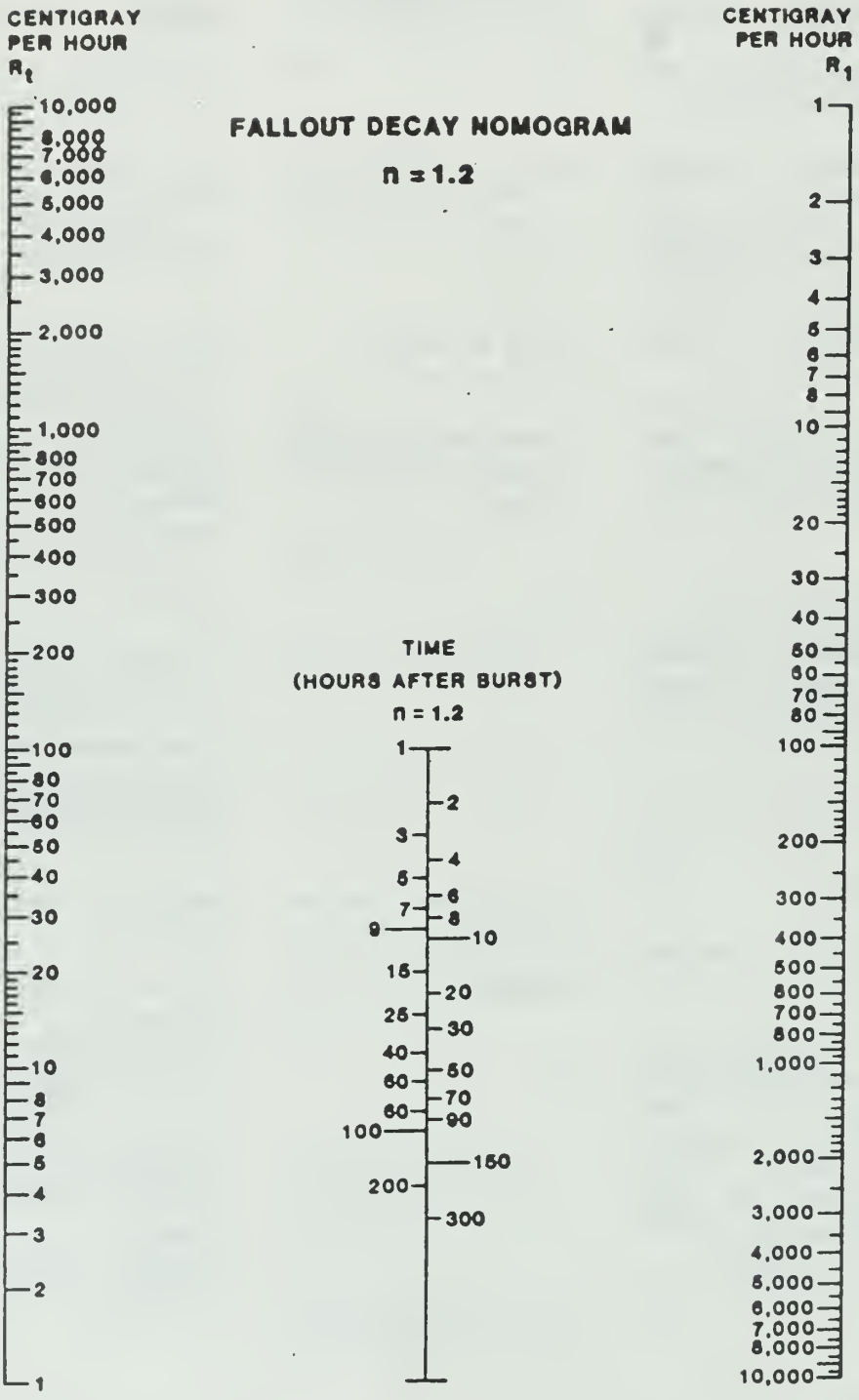
LINE	NUCLEAR	CHEMICAL AND BIOLOGICAL	REMARKS
A	Strike serial number.	Strike serial number.	Assigned by division NBC Center.
B	Position of observer.	Position of observer.	Use grid coordinates (or place).
C	Direction of attack from observer.	Direction of attack from observer.	Direction measured clockwise from grid north or magnetic north state which) in degrees or mils (state which).
D	Date-time group for detonation.	Date-time group for start of attack.	Zulu time.
E	Illumination time.	Date-time group for end of attack.	seconds.
F	Location of area attacked.	Location of area attacked. name.	Use grid coordinates (UTM) or place State whether location is actual or estimated.
G	Means of delivery.	Kind of attack.	State whether attack was by artillery, mortars, multiple rockets, missiles, bombs, or spray.
H	Type of burst.	Type of agent/type of burst. P (persistent) NP (non-persistent).	Estimate height of burst. Specify air, surface, or unknown for nuclear. State whether it was a ground or air burst or spray attack for chemical.
I	NA	Number of munitions or aircraft.	If known.
J	Flash-to-bang time.	NA	Use seconds.
K	Crater present or absent and diameter.	Description of terrain and vegetation.	Nuclear: Send in meters. Chemical: Sent in NBC 6.

MEANING OF LINE ITEMS IN NBC REPORTS (CONT)
(Ref: FM 3-3 w/ch 1, Table 2-1)

LINE	NUCLEAR	CHEMICAL AND BIOLOGICAL	REMARKS
L	Cloud width at H+5. min.	NA	State whether measured in degrees or mils.
M	Stabilized could top or bottom angle or cloud top or bottom height at H+10. min.	Enemy action before and after attack. Effect on troops.	Nuclear: State whether angle is measured in degrees or mils, or whether height is measured in meter or feet, and if cloud top or bottom. Chemical: Sent in NBC 6.
N	Estimated yield	NA	Sent as KT.
O	Date-time group for contour lines.	NA	Used when contours are not plotted at H+1.
P	Radar purposes only.	NA	
PA	Coordinates of external contours of radioactive cloud.	Predicated hazard area.	Chemical: If windspeed is 10 km/h or less, this item is 010 (the radius of the hazard area in km).
PB	Downwind direction of radioactive cloud.	Duration of hazard.	Nuclear: State whether direction is in degrees or mils. Chemical: In days.
Q	Location of reading.	Location of sampling and type of sample.	Chemical: State whether test was air or liquid.
R	Dose rate or actual value of decay exponent	NA	State in cGy/h. See sample NBC 4 for terms associated with this line.
S	Date-time group of reading.	Date-time group contamination detected.	State time initial indent-ification test sample or reading was taken.
T	H+1 date-time group. (hours)	Date-time group of latest contamination survey of the area.	NBC 5 and NBC 6 reports only.

MEANING OF LINE ITEMS IN NBC REPORTS (CONT)
(Ref: FM 3-3 w/ch 1, Table 2-1)

LINE	NUCLEAR	CHEMICAL AND BIOLOGICAL	REMARKS
U	1000-cGy/h. contour line.	NA	Plot in red.
V	300-cGy/h contour line.	NA	Plot in green.
W	100-cG/h contour line.	NA	Plot in blue.
X	20-cGy/h contour line.	Area of actual contamination.	Plot in black for nuclear, yellow for chemical.
Y	Direction of left and right adial lines.	Downwind direction of hazard and wind-speed.	Direction: 4 digits (degrees or mils). Windspeed: 3 digits (km/h or knots).
Z	Effective wind speed. Downwind distance of Zone I. Cloud radius.	NA	3 digits (km/h or knots). 3 digits (km or Num). 2 digits (km or Num). If windspeed is less than 8 km/h, this line contains only the 3-digit radius of Zone I.
ZA	NA	Significant weather phenomena.	See CDM for explanation of codes.
ZB	NA	Remarks.	Include any additional information
ZI	Effective wind speed. Downwind distance of Zone I. Downwind distance of Zone II. Cloud radius.	NA	3 digits (km/h). 4 digits (hundreds of meters). 4 digits (hundreds of meters). 3 digits (hundreds of meters).


CENTIGRAY
PER HOUR
R_t
10,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
800
700
600
500
400
300
200
100
80
70
60
50
40
30
20
10
8
7
6
5
4
3
2
1
FALLOUT DECAY NOMOGRAM
n = 1.2
TIME
(HOURS AFTER BURST)
n = 1.2
1
2
3
4
5
6
7
8
9
10
15
20
25
30
40
50
60
70
80
90
100
150
200
300
CENTIGRAY
PER HOUR
R_1
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
200
300
400
500
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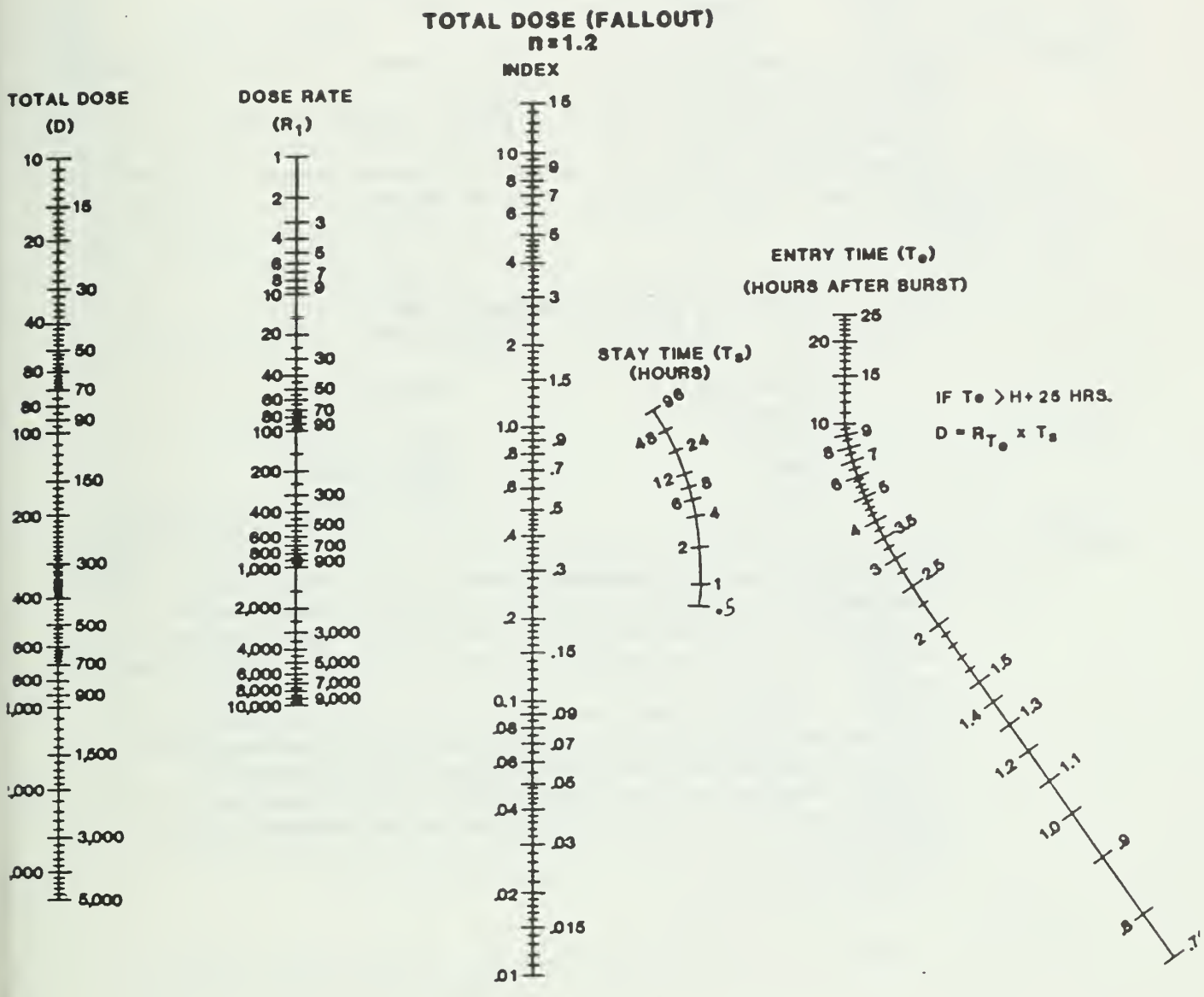
800
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
10,000


TOTAL DOSE (FALLOUT)
n=1.2
TOTAL DOSE
(D)
DOSE RATE
(R_1)
INDEX
STAY TIME (T_s)
(HOURS)
ENTRY TIME (T_e)
(HOURS AFTER BURST)
IF T_e > H+25 HRS.
$D = R_{T_e} \times T_s$

NBC WEATHER/WIND MESSAGES

Effective Downwind Message (EDM)
(Ref: FM 3-3 w/ch 1, Appendix E)

ZULU	DDTTTT DATE-TIME GROUP WINDS WERE MEASURED (ZULU)
ALFA	dddsss___ Over 0 thru 2 KT
BRAVO	dddsss___ Over 2 thru 5 KT
CHARLIE	dddsss___ Over 5 thru 30 KT
DELTA	dddsss___ Over 30 thru 100 KT
ECHO	dddsss___ Over 100 thru 300 KT
FOXTROT	dddsss___ Over 300 thru 1 MT
GOLF	dddsss___ Over 1 thru 3 MT

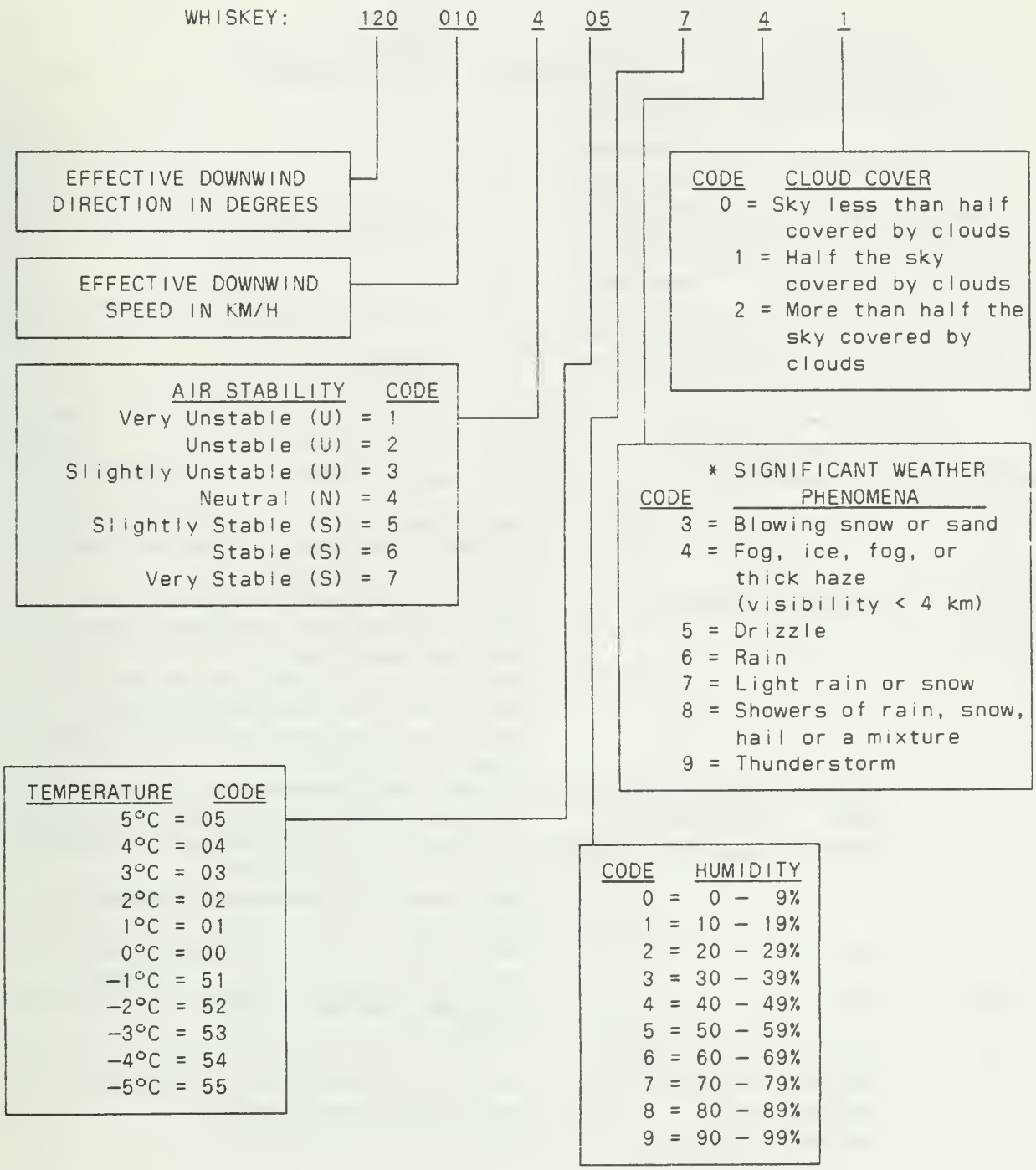
NOTES:
1. The first three digits (ddd) give the effective wind direction, in degrees, from grid north.
2. The second three digits (sss) give the effective wind speed in kilometers per hour.
3. The last three digits (___) give the expanded angle in degrees. (only used if fan is greater than 40 degrees)

Chemical Downwind Message (CDM)
(Ref: FM 3-3 w/ch 1, Appendix M)

110500 Zulu	110600 Zulu
I Corps	
WHISKEY	120010 418742
XRAY	125919 416742
YANKEE	130005 518642

NOTES:
1. CDM is only valid for 6 hours.
2. Area affected may be a mapsheet number or an area such as I CORPS.
3. Lines WHISKEY, XRAY, and YANKEE each contain coded weather information. Line WHISKEY is only valid for the first two hours, line XRAY for the next two hours, and line YANKEE for the last two hours.
4. The upper left-hand date/time group of the CDM message, in this case "110500," reflects the latest date/time up through which pertinent weather data was used to compile the message.
5. The upper right-hand date/time group of the CDM message, in this case "110600," is the date/time at which the message becomes effective.

HOW TO READ THE CODED WEATHER INFORMATION IN A CHEMICAL DOWNWIND MESSAGE
(Ref: FM 3-3 w/ch 1, Figure M-2)


WHISKEY: 120 010 4 05 7 4 1
EFFECTIVE DOWNWIND DIRECTION IN DEGREES
EFFECTIVE DOWNWIND SPEED IN KM/H
AIR STABILITY CODE
Very Unstable (U) = 1
Unstable (U) = 2
Slightly Unstable (U) = 3
Neutral (N) = 4
Slightly Stable (S) = 5
Stable (S) = 6
Very Stable (S) = 7
CODE CLOUD COVER
0 = Sky less than half covered by clouds
1 = Half the sky covered by clouds
2 = More than half the sky covered by clouds
* SIGNIFICANT WEATHER
CODE PHENOMENA
3 = Blowing snow or sand
4 = Fog, ice, fog, or thick haze (visibility < 4 km)
5 = Drizzle
6 = Rain
7 = Light rain or snow
8 = Showers of rain, snow, hail or a mixture
9 = Thunderstorm
TEMPERATURE CODE
5°C = 05
4°C = 04
3°C = 03
2°C = 02
1°C = 01
0°C = 00
-1°C = 51
-2°C = 52
-3°C = 53
-4°C = 54
-5°C = 55
CODE HUMIDITY
0 = 0 - 9%
1 = 10 - 19%
2 = 20 - 29%
3 = 30 - 39%
4 = 40 - 49%
5 = 50 - 59%
6 = 60 - 69%
7 = 70 - 79%
8 = 80 - 89%
9 = 90 - 99%

* The significant weather code can also be written as a dash (-) if the weather is clear or unknown.

NUCWARN (FRIENDLY NUCLEAR STRIKE)
(Ref: FM 3-3 w/ch 1, Table 2-2)

LINE	MULTIPLE	SINGLE
A	Lamp Post	AC002
D	162025Z-162155Z	270915Z-270930Z
F2	PA613423	
	PA616515	
	PA655523	
	PA631450	
	PA625413	
F3	PA602403	011 PA215154
	PA605536	
	PA672552	
	PA642472	
	PA673442	
H	3 Surface	Surface
I	22	

Line/Letter	Meaning	Remarks
A	Target number of code.	Use target number such as AF001 single attack. Use code such as Hot Candle, for multiple attacks.
D	Date-time groups.	Single: Date and time attack will begin and the date and time attack will be cancelled. Multiple: Date and time attack will begin and date and time when all bursts will be complete. This line should be encoded.
F1	Minimum safe distance 1 (MSD 1) and location of single or multiple attack.	Single: MSD in hundreds of meters followed by UTM grid coordinates of GZ or DGZ will be included only in the first Foxtrot line sent). Multiple: UTM grid coordinates of MSD1 box.
F2	MSD 2.	Same as F1 except information pertains to MSD 2.
F3	MSD 3.	Same as F1 except information pertains to MSD 3.
H	Type burst and number of bursts. (surface or sub-surface only)	If there is any chance that the strike will be a surface or subsurface burst this line is sent.
I	Number of bursts.	For multiple bursts only.

PROTECTION REQUIREMENTS FOR FRIENDLY NUCLEAR STRIKE

(Ref: FM 3-3 w/ch 1, Table 2-3)

Area	Limit of Negligible Risk to:	Zone of Warning	Protection Requirement
DGZ to MSD 1 (F1)	- - - - - - - - - - - -	1	Evacuate all personnel
MSD 1 to MSD 2 (F1 to F2)	Warned, protected personnel.	2	Personnel in buttoned up tanks or foxholes with overhead cover.
MSD 2 to MSD 3 (F2 to F3)	Warned, exposed personnel.	3	Personnel are prone on ground with all skin area covered.
MSD 3 and beyond (F3 to beyond)	Unwarned, exposed personnel.	- - - -	No protective measures except dazzle and EMP.

SIGNIFICANCE OF PREDICTED FALLOUT ZONES

Exposed, unprotected people may receive the following doses from fallout.

Zone I — Immediate operational concern
More than 150 cGy within 4 hours

Zone II — Secondary hazard.
Less than 150 cGy within 4 hours
More than 50 gGy within 24 hours

Outside the predicted area
No more than 50 cGy in 24 hours
No more than 150 cGy for an indefinite period

CHEMWARN (FRIENDLY CHEMICAL STRIKE)
(Ref: FM 3-3 w/ch 1, Table 2-4)

A	AF002Chem
D	020830
F	PG 560750
G	Artillery Ground Burst
H	Persistent Nerve
PA	PG 556751
	PG 559754
	PG 632774
	PG 610694
	PG 558747
PB	In Attack Area 2 - 4 days
	In Hazard Area 1 - 2 days
Y	0015 Deg, 15 km/h

NOTE: A CHEMWARN message is plotted like an NBC 3 (chemical) report.

CHEMWARN FORMAT

Line/Letter	Meaning	Remarks
A	Strike serial number or code chemical attack.	Indicate that this is a word.
D	Date-time group of attack.	Only the date and time of the attack is given. This should be encoded.
F	Location of attack.	Grid coordinates of center of attack. If attack is spread over large area, a series of coordinates may be given to indicate the center of mass of the attack. This should be encoded.
G	Delivery means.	Tell how delivered and how disseminated.
H	Type of agent.	Classify agent by physiological effect and duration of effectiveness.
PA	Attack Area and predicated hazard area.	When wind speeds are 10 km/h or less, this line will be 010, (the radius of hazard area is in km). When wind speeds are higher than 10 km/h, 6-digit coordinates will be given.
PB	Duration of hazard.	In days.
Y	Downwind direction and wind speed.	Downwind direction: 4 digits in degrees or mils (state which). Windspeed: 3 digits in km/h only.

NUCLEAR RADIATION DEGREE OF RISK EXPOSURE
(Ref: FM 3-3 w/ch 1, Table J-2)

OEG = Degree of Risk – Prior Exposure OR

OEG = Degree of Risk – Average Value for RES Category

Total Cumulative Dose (cGy) before exposure	RES Category	Average Value for RES Category
No exposure	RES-0	0 cGY
Some exposure but not greater than 70	RES-1	40 cGy
Greater than 70 but less than or equal to 150	RES-2	110 cGy
Greater than 150	RES-3	Greater than 150 cGy

Single Exposure Criteria	
Negligible Risk:	50 cGy
Moderate Risk :	70 cGy
Emergency Risk :	150 cGy

BATTALION OR COMPANY RADIATION STATUS CATEGORY
(Ref: FM 3-3 w/ch 1, Table J-3)

BATTALION OR COMPANY RS CATEGORY	NUMBERS OF COMPANIES IN BATTALION OR PLATOONS IN COMPANY					
	2	3	4	5	6	7
	SUM OF RS NUMBERS OF ALL PLATOONS OR COMPANIES					
RS-0	0	0 - 1	0 - 1	0 - 2	0 - 2	0 - 3
RS-1	1 - 2	2 - 4	2 - 5	3 - 7	3 - 8	4 - 10
RS-2	3 - 4	5 - 7	6 - 9	8 - 12	9 - 14	11 - 17
RS-3	5 - 6	8 - 9	10 - 12	13 - 15	15 - 18	18 - 21

FIELD RADIAC INSTRUMENTS

Instrument	Use	Measures	Range
IM 9/PD	Clinical Dosimeter	Gamma Dose	0-200 milliroentgen
IM 93 UD	Tactical Dosimeter	Gamma Dose	0-600 roentgen
IM 147/PD	NBC Team Dosimeter	Gamma Dose	0-50 roentgen
PP 1578A/PD	Dosimeter Charger IM 9, IM 93, and IM 147		
AN/PDR 27	Personnel and Equipment Survey	Gamma Dose Rate Detects Beta	0-500 milliroentgen/hour over four scales
IM 174A/PD	Area Survey	Gamma Dose Rate	0-500 rad/hour
DT 236	Tactical Dosimeter (Wristwatch Design)	Neutron and Gamma Dose	0-1000 rads
AN/VDR 2	Personnel and Equipment Survey	Gamma Dose/rate Beta Detection	1-1000 rad/hr

FIELD CHEMICAL DETECTION EQUIPMENT

Detection Equipment	Identifies	Reaction Time
Paper, Chem Agent Detector, VGH, ABC – M–8	Nerve & Blister Liquid	Few seconds to 1 minute
Paper, Chem Agent Detector, M–9	Liquid Agents	Few seconds
Detector Kit, Chem Agent, M256	Nerve, Blood, Blister Vapor	16 minutes
H20 Testing Kit, Chem Agent, M272	Blood, Blister, Nerve	10 minutes
Chemical Agent Monitor (CAM)	Nerve, Blister Vapor	————
M8A1 Automatic Chemical Agent Alarm	Nerve, Vapor	Few seconds

CHEMICAL DOWNWIND HAZARD PREDICTION

DETERMINATION OF ATTACK TYPE AND CASE
(Ref: FM 3-3 w/ch 1, Table N-1)

TYPE ATTACK *	CASE	ATTACK AREA	WIND SPEED	DOWNWIND HAZARD
AIR (A) (vapor)	a	1 km	≤ 10 km/h	10 km circle
	b	1 km	> 10 km/h	10, 15, 30 or 50 km ***
GROUND (B)** (liquid)	a	≤ 1 km	> 10 km/h	10 km
	b	> 1 km to ≤ 2 km	> 10 km/h	10 km
	c	> 2 km distance	> 10 km/h	10 km
	d	same as case a, b, or c	≤ 10 km/h	10 km circle

* Assume attacks to be Type A unless there is unmistakable evidence of ground contamination.

** If the size of the attack area is not known the attack will be assumed to by Type B, case b.

*** Downwind hazard depends of the means of delivery and temperature gradient

NOTES: 1. Examples of air contaminating (non-persistent) agents are: Blood (AC, CK), Nerve (G series), and Choking (CG).
2. Examples of ground contaminating (persistent) agents are: Blister (H series, L, CX) and Nerve (V, TGD)

CHEMICAL HAZARD PLOTTING STEPS
(Ref: FM 3-3 w/ch 1, Appendix N)

Procedure:

Type A. Case a

1. Plot attack location.
2. Draw a 1 km radius circle, label as "attack area".
3. Draw 10 km radius circle, label as "hazard area".
4. Send NBC 3 (Chem).

Type A. Case b

1. Plot attack location.
2. Draw grid north line.
3. Draw 1 km radius circle, label as "attack area."
4. Draw a line from attack center in the downwind direction (from CDM).
5. Extract hazard distance from table. Plot downwind distance and draw a line perpendicular to the downwind direction.
6. Extend downwind line 2 km upwind from the attack center. Draw tangent lines from this point, label as "hazard area".
7. Send NBC 3 (Chem).

Type B, Case a

1. Plot as type A, case b. The maximum downwind hazard distance is 10km.

Type B, Case b

1. Plot attack location.
2. Draw grid north line.
3. Draw a 2 km radius circle, label as "attack area".
4. Draw a line from attack center in the downwind direction (from CDM) 10 km. Draw a line perpendicular to the downwind direction.

5. Extend downwind line 4 km upwind from the center of the attack location. Draw tangent lines from this point, label as "hazard area".

6. Send NBC 3 (Chem).

Type B, Case c

1. Plot attack area. Identify a point at each extreme end.

2. Draw a 1 km circle around each point.

3. Draw a downwind direction line 10 km from the most downwind circle. Draw a short line downwind from the other point, label as "attack area". Extend both lines 2 km upwind.

4. Draw a line perpendicular to the downwind direction line...

5. Draw tangent lines, label as "hazard area".

6. Send NBC 3 (Chem).

Type B, Case d

1. Derive the attack location from an NBC 1 or NBC 2 report and plot the location on a map or template.

2. Draw a 10 kilometer radius circle around the attack area center, label as "hazard area".

3. Draw the appropriate radius around the center of attack as per means of delivery, label as "attack area".

4. Send an NBC 3 (Chem) to units/installations in the hazard area.

TABLES FOR USE IN CHEMICAL DOWNWIND HAZARD PREDICTION

TABLE 1

AIR STABILITY CATEGORY
BASIC CHART
(Ref: FM 3-3 w/ch 1, Fig. M-3)

TIME OF DAY AND ANGLE OF SUN		CONDITION OF SKY		
		Less than half covered	More than half covered	Overcast
MORNING	≤4°	S	S	N
	>4° and ≤32°	N	N	N
	>32° and ≤40°	U	N	N
	>40°	U	U	N
EVENING	>46°	U	U	N
	>35° and ≤46°	U	N	N
	>12° and ≤35°	N	N	N
	>5° and <12°	S	N	N
	≤5°	S	S	N

NOTE: The Stability Category found in this Table must be adjusted to conditions of weather and terrain by using Table 2.

STABILITY CATEGORY ADJUSTMENT
(Ref: FM 3-3 w/ch 1, Fig. M-4)

TABLE 2

AIR STABILITY CATEGORY ADJUSTMENT CHART			
WEATHER AND TERRAIN All eight conditions given below must be checked. If more than one applies, choose the most stable category.	STABILITY CATEGORY FROM BASIC CHART		
	U	N	S
Dry to slightly moist surface	U	N	S
Wet surface (e.g., after continuous rain or dew)	N	N	S
Frozen surface or partly covered with snow, frost, or hoarfrost	N	S	S
Surface completely covered with snow	S	S	S
Continuous rainfall	N	N	N
Haze or mist (visibility 1-4 km)	N	N	S
Fog (visibility less than 1 km)	N	S	S
Downwind speed more than 18 km	N	N	N

NOTES:
1. Table 2 is used for adjustment of the stability category found from Table 1, taking into account influences of surface and weather.
2. All eight conditions of terrain and weather listed in Table 2 must be checked, and, in case of doubt, the most stable category is to be chosen.

TYPE "A" ATTACK
(Ref: FM 3-3 w/ch 1, Table N-2)

DOWNWIND DISTANCE OF HAZARD AREA

TABLE 3

Means of Delivery	Distance from center of attack area along downwind axis, when the air stability category is:		
	U	N	S
Artillery, Bomblets, and Mortars	10 km	30 km	50 km
Multiple Rocket Launchers, Missiles, Bombs, and Unknown Munitions	15 km	30 km	50 km

NOTE: When no information is available on the nature of the munitions used in the attack, use the figures given for multiple rocket launchers, missiles and bombs.

TYPE "B" ATTACK
(Ref: FM 3-3 w/ch 1, Table N-3)

PROBABLE TIME AFTER GROUND CONTAMINATION
WHEN PERSONNEL MAY SAFELY REMOVE MASKS

TABLE 4

Daily Mean Surface Air Temperature	Within Attack Area (number of days)	Within Hazard Area (number of days
<0° – 10°C (32–50°F)	3 to 10 days	2 to 6 days
11° – 20°C (51–68°F)	2 to 4 days	1 to 2 days
21° – >30°C (69–86°F)	up to 2 days	up to 1 day

NOTE: Tests for presence of chemical agent contamination and/or proper unmasking procedures must always be used before unmasking after a chemical attack or in any area where a chemical agent hazard might exist.

NOTES:
1. The estimates assume ground contamination densities of up to 10 g/m^2.
2. In making hazard estimates, vapor has been considered to be the determining factor within the attack area as well as in the downwind hazard area, however, the duration of hazard from contact with bare skin is difficult to predict. Duration can only be determined by the use of chemical agent detection or confirmation devices.
3. When temperatures are consistently low, the duration of ground contamination may be longer than indicated in the Table. The absence of vapors does not preclude the presence of contamination
4. Daily, mean, surface air temperature may be obtained from the local meteorology (MET) officers.

BIOLOGICAL DOWNWIND HAZARD PREDICTION

CLOUD DURATION OF GREATEST EFFECTS IN ZONE I*
(Ref: FC 3-3-2)

Type	Cloud duration
Pathogens, Hardened (engineered or spore)	8 hours
Pathogens, Non-hardened **	Number of hours from time of attack to BMNT + 2 hrs (max of 8 hours) (min of 2 hours)
Toxins	8 hours

* The actual effectiveness to minimum hazard levels may extend to as much as 32 hours, or four (4) times the cloud duration of greatest effects (4 X 8 = 32).

** If a Biological Agent is delivered <u>after</u> BMNT and prior to that day's sunset it is automatically treated as a hardened pathogen with an 8 hour cloud duration.

MAXIMUM DOWNWIND HAZARD DISTANCE (MDWHD):

MDWHD = 4 X wind speed (km/hr) X cloud duration of greatest effects.

TIME OF CLOUD ARRIVAL (T_{car}):

$$(T_{car}): = \text{Time of attack} + \frac{\text{Distance from attack area (km)}}{\text{Wind speed (km/hr)}}$$

TIME OF CLOUD EXPOSURE (T_{cex}):

$$(T_{cex}): = \frac{\text{Distance from attack area (km)}}{3 \text{ X Wind speed (km/hr)}}$$

DETERMINATION OF ATTACK TYPE AND CASE

BIOLOGICAL HAZARD PREDICTION
(Ref: FC 3-3-2)

Hazard	Attack Type	Type	Case
Aerosol (air contaminating)	Point or Area of Attack	A	a
	Spray Line Attack	A	b
Large Liquid Drops (ground contaminating)	NA	B	NA

Procedure: Biological Hazard Plotting Steps

Type A, case a

1. Plot attack location.
2. Draw a circle with a radius equal to the radius of the attack area plus 1 km (minimum radius of 1 km)
3. Determine the MDWHD.
4. Draw a line equal in length to the MDWHD from attack center toward the downwind direction (from CDM).
5. Draw a line perpendicular to the downwind direction which intersects the end-point of the MDWHD line.
6. Extend the downwind line twice the radius of the circle upwind.
7. Draw tangent lines from this upwind point.
8. Divide the MDWHD by 4. Plot this distance along the MDWHD line: Draw a perpendicular at this point to define the Zone I endline.
9. Send the NBC 3 (Bio).

Type A, case b

1. Plot attack area. Identify a point at each extreme end.
2. Draw a 1 km circle around each point.
3. Determine the MDWHD.
4. Draw a line equal in length to the MDWHD from the center of the most downwind circle toward the downwind direction.
5. Draw a line perpendicular to the downwind direction which intersects the endpoint of the MDWHD line.
6. Draw a short downwind line from the most upwind circle.
7. Extend both downwind lines 2 km upwind.
8. Draw tangent lines form these upwind points.
9. Divide the MDWHD by 4. Plot this distance along the MDWHD line. Draw a perpendicular at this point to define the Zone I endline.
10. Send the NBC 3 (Bio).

Type B

1. Plot attack location.
2. Draw a circle with a radius equal to the radius of the attack area plus 1 km (minimum radius of 5 km).
3. Send the NBC 3 (Bio).

MEANING OF ZONES FOR BIOLOGICAL AREAS

Zone I—more than 20–30% casualties.

Zone II—20–30% casualties, gradually decreasing to 1–3%.

Outside the predicted area—no more than 1–3% casualties. The biological hazard is no greater than normal.

FALLOUT PREDICTION
(Ref: FM 3-3)

1. Simplified Fallout Prediction

   a. Locate GZ and identify DTG

   b. Determine yield (illumination time, cloud-top or bottom angle versus flash-to-bang time, or flash-to-bang time versus cloud width, pp. 33, 34, 35)

   c. Determine wind data from current effective downwind message

   d. Determine Zone I and Zone II (pp. 36)

   e. Determine cloud radius (pp. 37)

   f. Plot parameters

      (1) Wind direction azimuth

      (2) Fan 20 degrees either side of wind direction

      (3) H+1, H+2 time of arrival arcs

      (4) Zone I and Zone II arcs

      (5) Cloud radius

      (6) Connect Zone I arc tangent to cloud radius

2. Detailed Fallout Prediction

   a. Located GZ and identify DTG

   b. Draw radial lines

   c. Draw H+1, H+2 time of arrival arcs

   d. Draw Zone I and Zone II arcs

   e. Draw cloud radius

   f. Connect Zone I arc tangent to cloud radius

3. ANALYZE THE POTENTIAL EFFECT ON YOUR OPERATIONS

PREPARATION OF A DETAILED FALLOUT PREDICTION FROM THE NBC - 3 (NUCLEAR REPORT)
(Ref: FM 3-3 w/ch 1, Appendix D,)

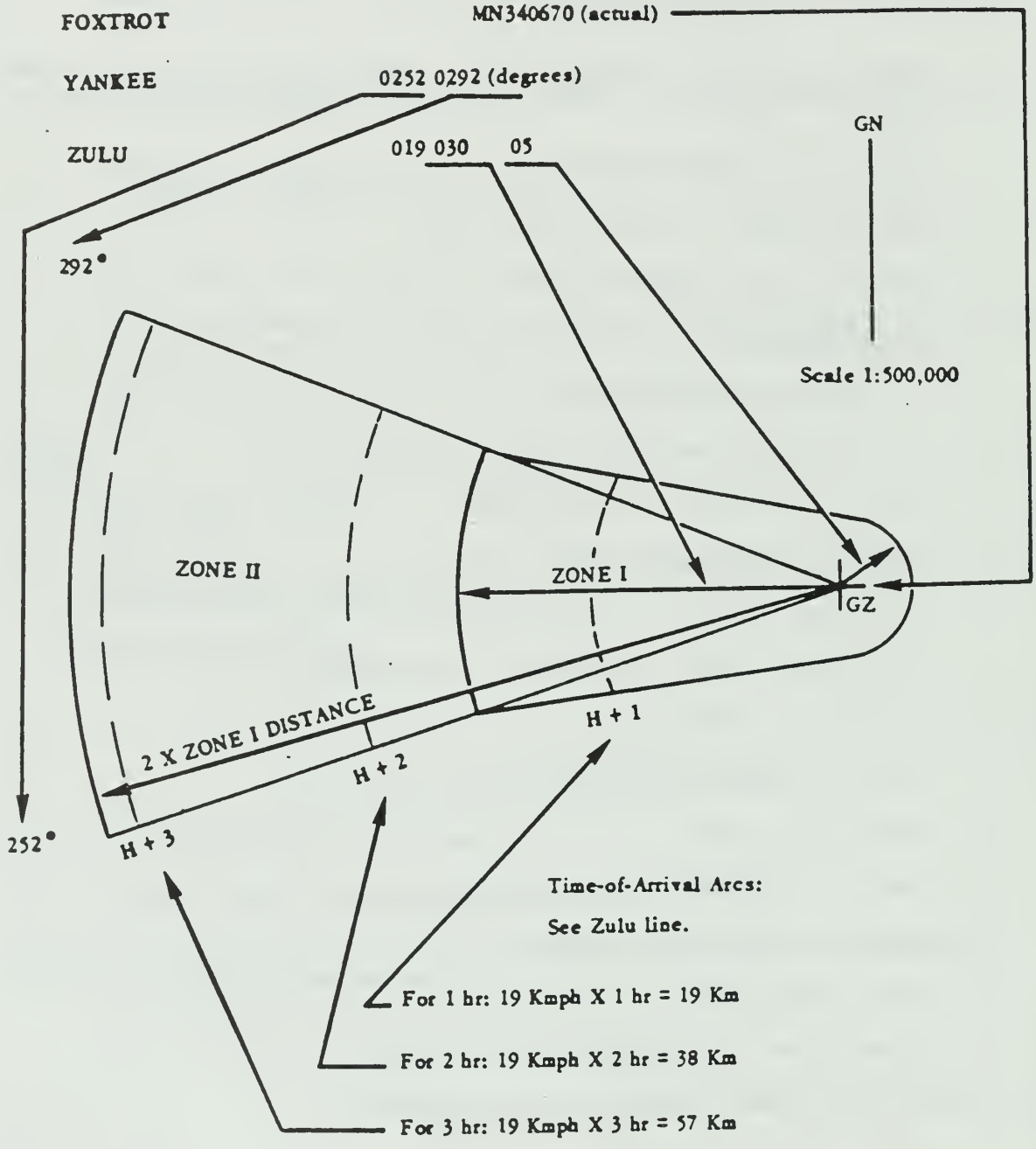
ALFA 24

DELTA 240700Z

FOXTROT MN340670 (actual)

YANKEE 0252 0292 (degrees)

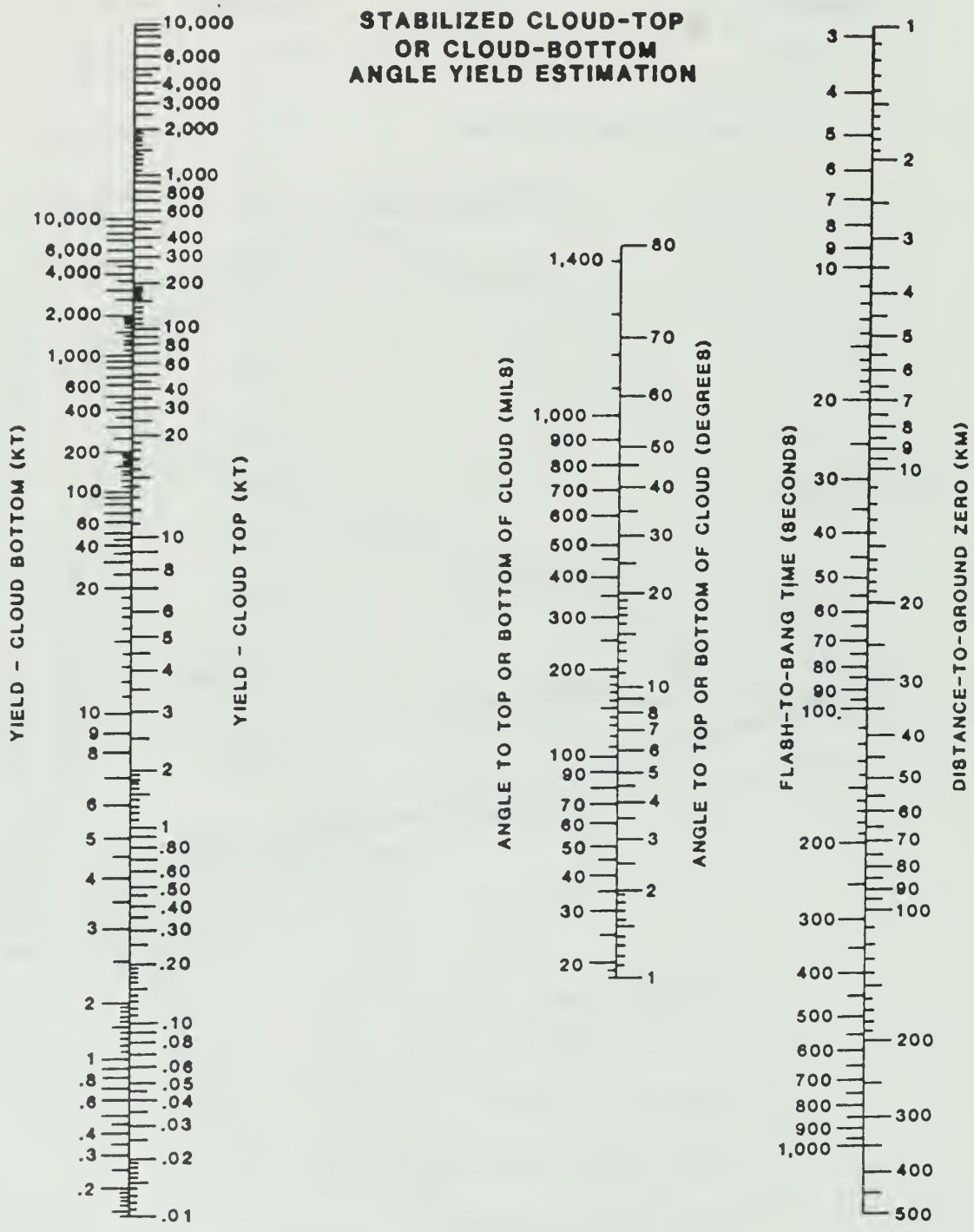
ZULU 019 030 05



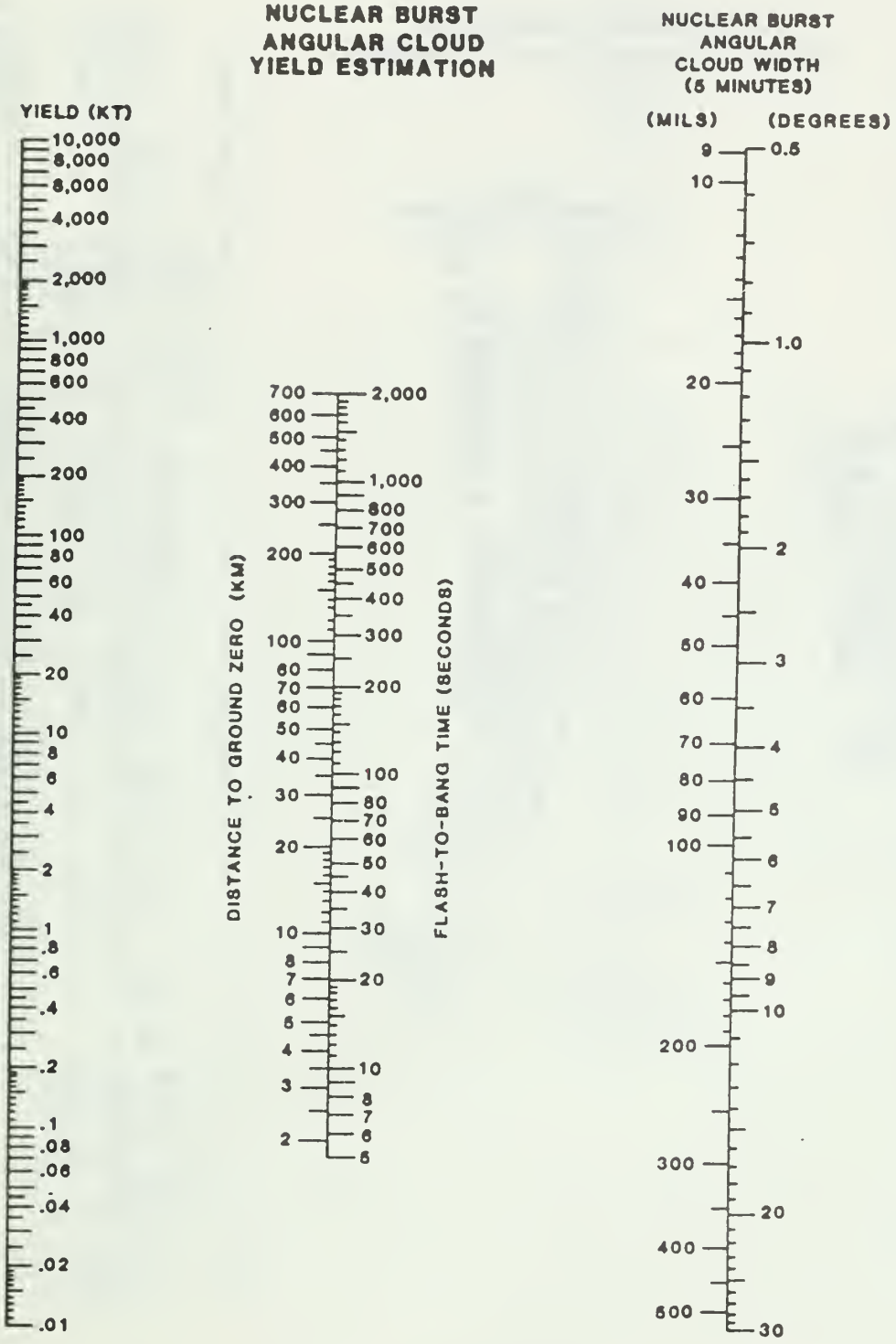
YIELD ESTIMATION VERSUS ILLUMINATION TIME
(Ref: FM 3-3 w/ch 1, Table B-1)

Illumination Time (Seconds)	Yield (KT)
Less than 1	1 to 2
1	2.5
2	10
3	22
4	40
5	60
6	90
7	125
8	160
9	200
10	250
12	325
14	475
16	700

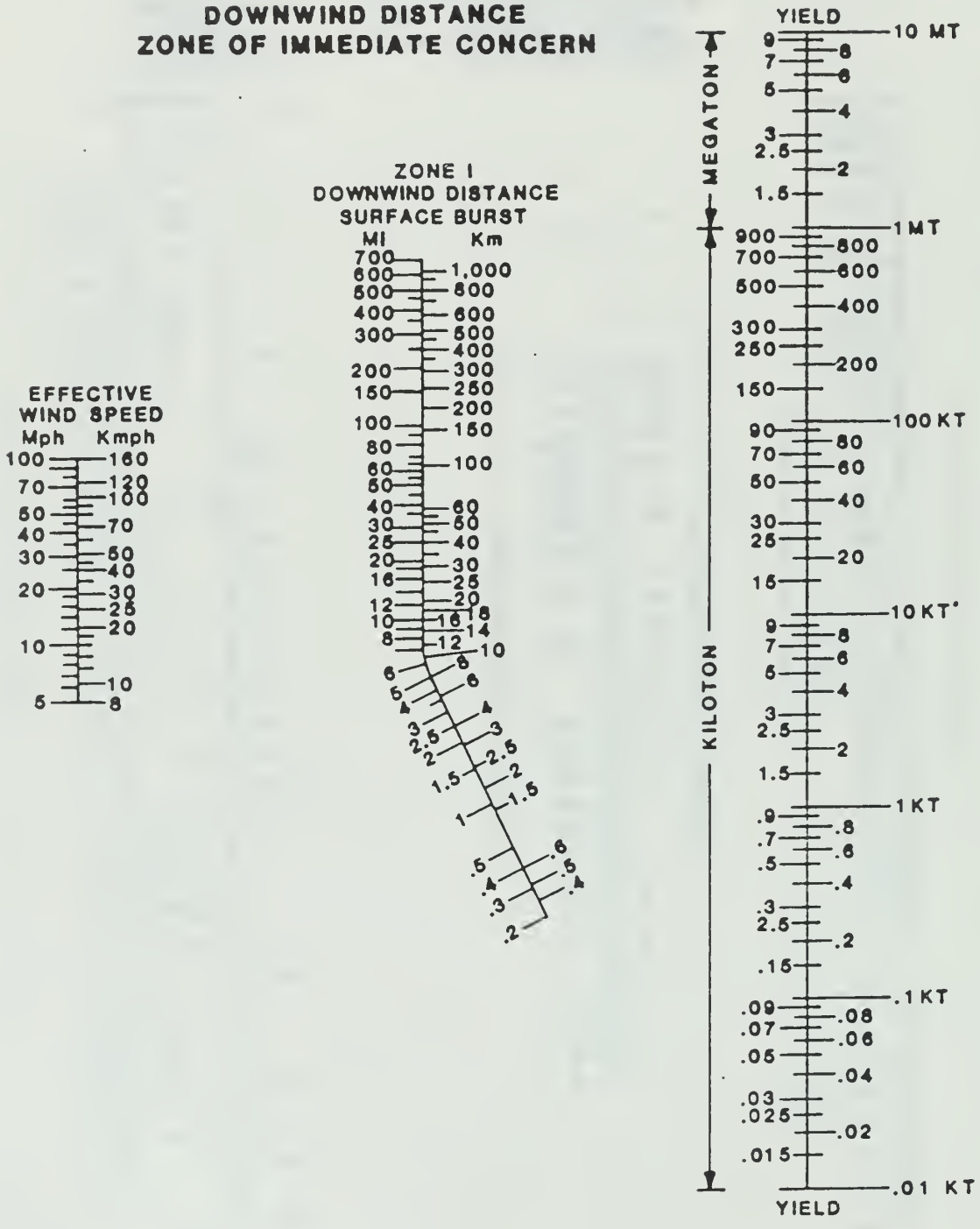
YIELD ESTIMATION (FLASH TO BANG TIME VERSUS
STABILIZED CLOUD TOP ANGLE OR STABILIZED CLOUD BOTTOM ANGLE)
(Ref: FM 3-3 w/ch 1, Figure B-5)


STABILIZED CLOUD-TOP
OR CLOUD-BOTTOM
ANGLE YIELD ESTIMATION
YIELD - CLOUD BOTTOM (KT)
YIELD - CLOUD TOP (KT)
ANGLE TO TOP OR BOTTOM OF CLOUD (MILS)
ANGLE TO TOP OR BOTTOM OF CLOUD (DEGREES)
FLASH-TO-BANG TIME (SECONDS)
DISTANCE-TO-GROUND ZERO (KM)

YIELD ESTIMATION (FLASH TO BANG TIME VERSUS
NUCLEAR BLAST CLOUD WIDTH AT FIVE MINUTES AFTER DETONATION)
(Ref: FM 3-3 w/ch 1, Figure B-3)



DOWNWIND DISTANCE OF ZONE I: ZONE OF IMMEDIATE OPERATIONAL CONCERN
(Ref: FM 3-3 w/ch 1, Figure D-7)



CLOUD RADIUS (STABILIZED AT H+10 MINUTES)
(Ref: FM 3-3 w/ch 1, Figure D-3)

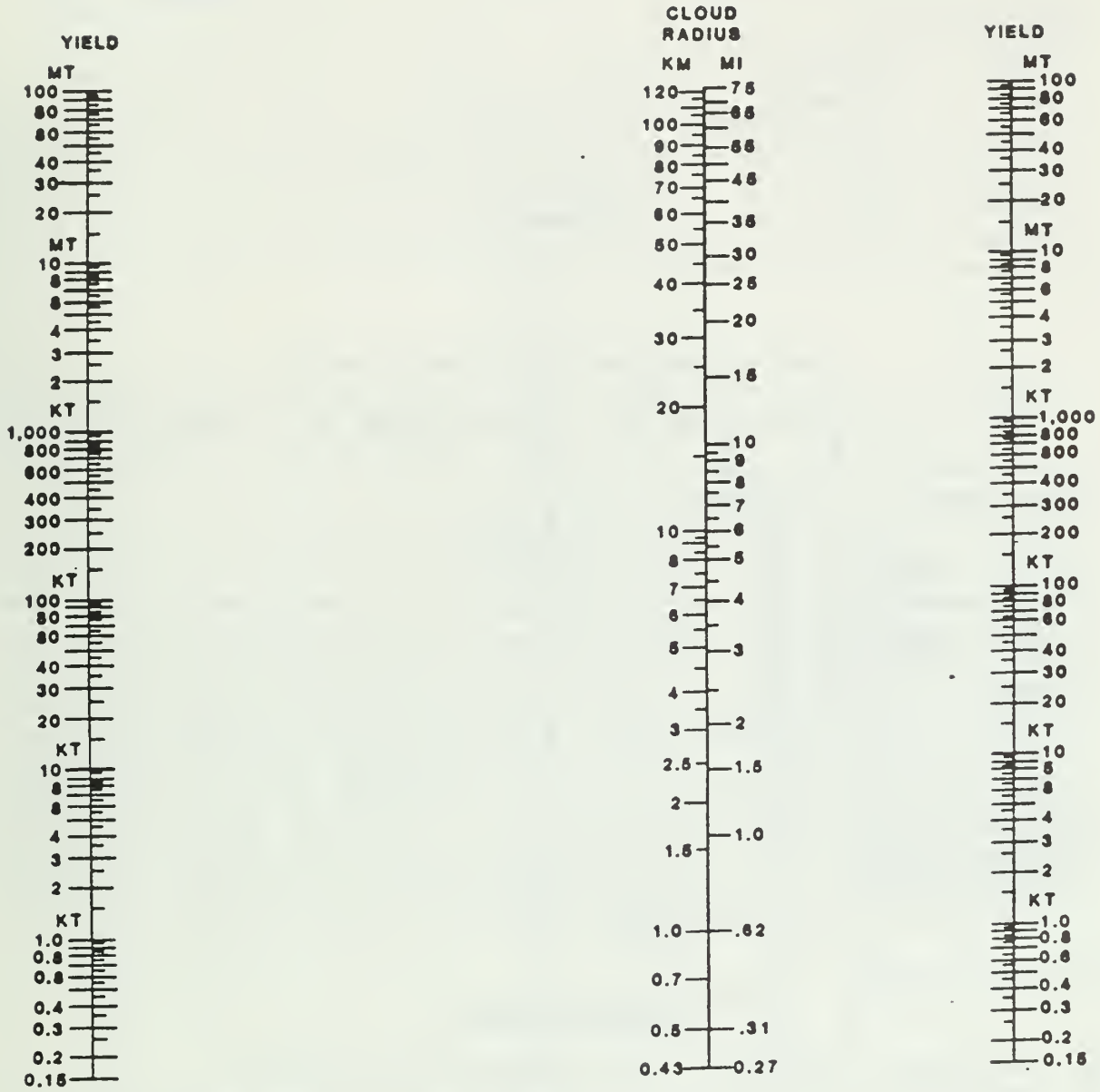


Table 23 Air Burst—Exposed—15–25 KT (Casualty Classes by %)

Radius: 50–150 m.	K	Rs Bc W	Rs Bc	Rs Bf W	Rs Bf	Rs W	Rs	Rm Bc W	Rm Bc	Rm Bf W	Rm Bf	Rm W	Rm	Bc W	Bc	Bf W	Bf	W
Offset Dist. (meters): 0–450	100																	
450–650	70	10	20															
650–1100	10	30	60															
1100–1400	10	15	30					15	30									
1400–1600	10									10	25	5	5			10	25	5
1600–1850	10															20	50	10
1850–2250																	5	

Table 27. Air Burst—Exposed—15–25 KT (Casualty Classes by %)

Radius: 450–550 m.	K	Rs Bc W	Rs Bc	Rs Bf W	Rs Bf	Rs W	Rs	Rm Bc W	Rm Bc	Rm Bf W	Rm Bf	Rm W	Rm	Bc W	Bc	Bf W	Bf	W
Offset Dist. (meters): 0–150	85	5	10															
150–250	80	5	15															
250–350	70	10	20															
350–450	60	15	25															
450–650	45	20	35															
650–850	20	25	50						5									
850–1100	10	25	45					5	5		5						5	
1100–1400	10	15	25					5	10	5	10					5	10	
1400–1600	10	5	10						5	5	10					10	30	5
1600–1850	5	5	5						5		5					15	50	5
1850–2250	5															10	45	5
2250–2500																	10	

Casualty Symbols

Ks – The casualty dies within 6 hours following the explosion.

Rs – Severe ionizing radiation injury manifested by incapacitating signs and symptoms within 2 – 4 hours. Prognosis is guarded and high probability of fatal out come.

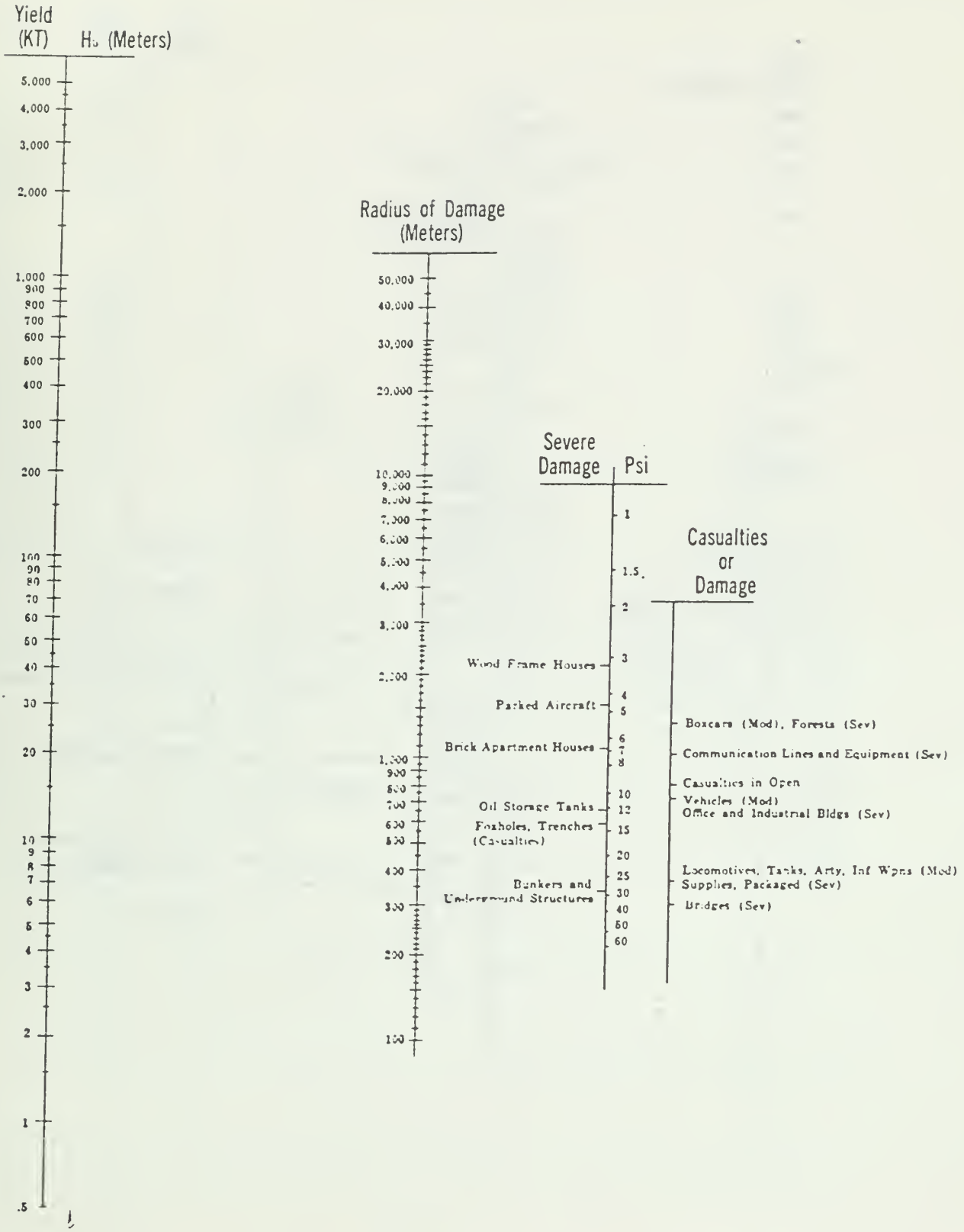
Rm – Moderate ionizing radiation injury manifested by sign and symptoms which occur later than 5 to 6 hours following the explosion. The prognosis is favorable and there is a low probability of a fatal outcome.

Bf – Thermal burns, 2 – 3 degree on the face.

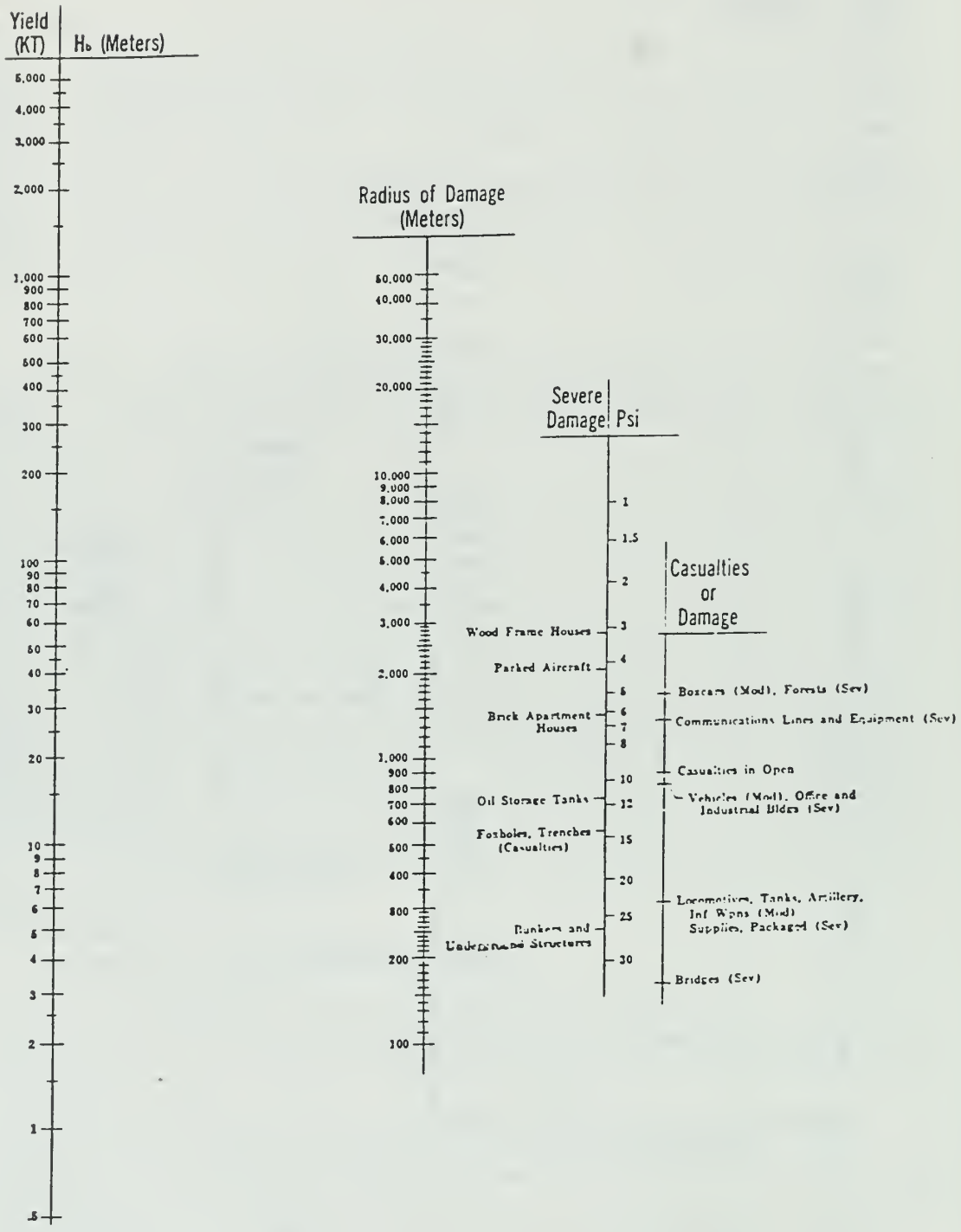
Bc – Thermal burns, 2 – 3 degree, occurring under clothing and affecting up to 25% of the body surface.

W – Wounds, fractures, or other mechanical trauma.

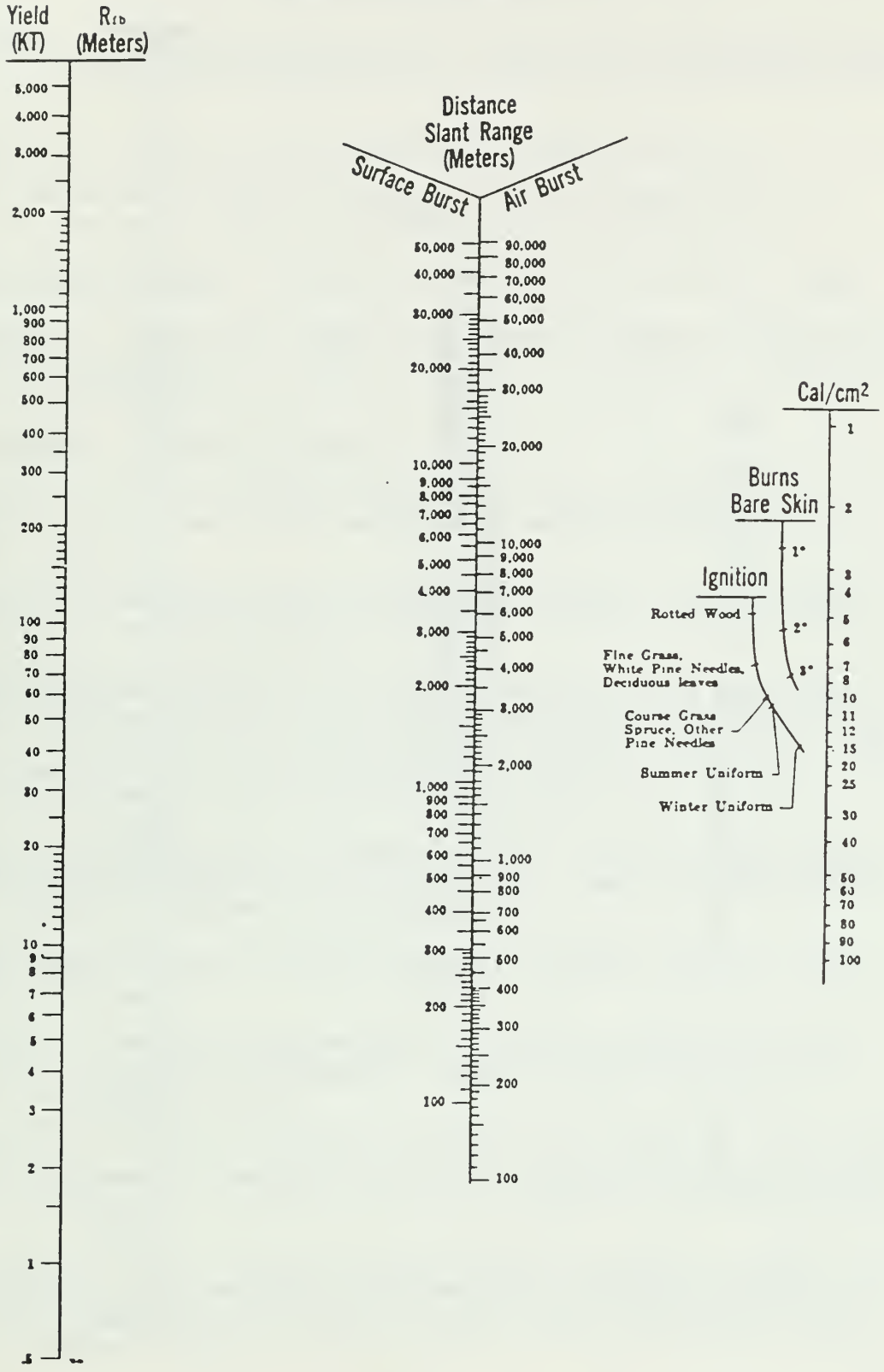
BLAST DAMAGE, SURFACE BLAST



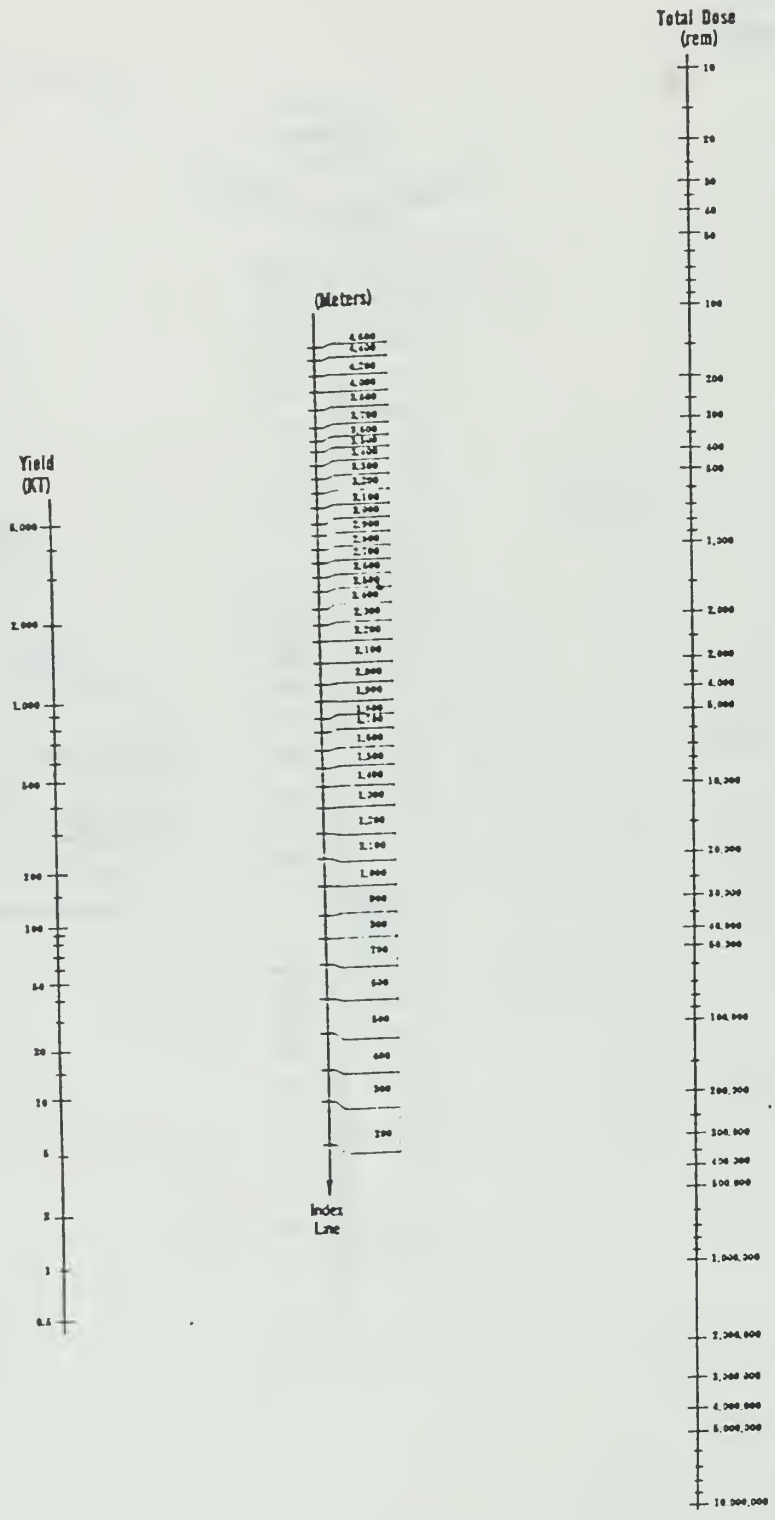
BLAST DAMAGE, LOW AIR BURST



THERMAL RADIATION, AIR AND SURFACE BURSTS



COMBINED INITIAL NUCLEAR RADIATION
AIR AND SURFACE BURSTS



GLOSSARY OF TERMS

ABSORBED DOSE – The energy imparted to matter by ionizing radiation per unit mass of irradiated (absorbing) material. The unit of absorbed dose is the gray (1Gy = 100 rad).

ACTIVATION – The process of inducing radioactivity by irradiation.

ACTIVITY – The number of nuclear transformations (disintegrations) in a specified time period, usually per second, per minute, etc.

ACUTE (RADIATION EXPOSURE) – Extending over a period of 24 hours or less.

ALPHA PARTICLE – A positively charged particle emitted from the nucleus of an atom, having a mass equal in magnitude to a helium nucleus. Also generally termed alpha radiation.

AMBIENT PRESSURE – Atmospheric pressure.

ATOM – The smallest particle of an element that still retains the characteristics of that element and which is capable of entering into a chemical reaction.

ATTENUATION – The process by which the radiation exposure rate is reduced when passing through some material.

BACKGROUND RADIATION – Nuclear or ionizing radiations arising from within the body and from the surroundings to which individuals are always exposed. The main sources of natural background radiation are potassium–40 in the body, potassium–40 and thorium, uranium, and their decay products (including radium) present in rocks and cosmic rays.

BASIC SKILLS DECONTAMINATION – The immediate neutralization or removal of contamination from exposed portions of the skin. Each individual must be able to perform this decon without supervision.

BETA BURNS – Superficial skin injury, similar to a sunburn, caused by beta irradiation.

BETA PARTICLE – A negatively charged particle having a mass equal to the electron. It is emitted spontaneously from the nuclei of certain radioactive elements.

CHAIN REACTION – In a nuclear weapon the uncontrolled release of neutrons each of which interacts with another atom causing a geometric increase in the number of fissions.

CHAMBER, POCKET – A small rechargeable device used for monitoring the radiation exposure of personnel. The amount of discharge is a measure of the radiation exposure. (An example of this type of instrument is the tactical dosimeter IM 93).

CHARGED PARTICLES – Elementary particles that carry an electric charge, e.g., electrons and protons. The nuclei of some light elements are also referred to as charged particles: the deuteron, triton, and alpha particle.

CHEMICAL SURVEY – A directed effort to determine the nature and degree of chemical hazard in an area and to set boundaries of the hazard area.

CHRONIC (RADIATION EXPOSURE) – Exposure to small amounts of radiation ($\leq$ 19 cGy) over a long period of time.

CLOUD BOTTOM ANGLE – The angle between the surface of the earth and the bottom of the stabilized nuclear cloud measured at H + 10 minutes.

CLOUD TOP ANGLE – The angle between the surface of the earth and the top of the stabilized nuclear cloud measured at H + 10 minutes.

CLOUD WIDTH – The width of the nuclear cloud, measured in degrees or radians, determined at H + 5 minutes.

COLLECTIVE PROTECTION – A shelter, with filtered air, that provides a contamination free working environment for selected personnel and allows relief from continuous wear of MOPP gear.

CONTAMINATION – (1) Deposit or absorption of radioactive material or biological agents or chemical agents on and by structures, areas, personnel, or objects. (2) Food or water made unfit for human or animal consumption by the presence of environmental chemicals, radioactive elements, bacteria, or organisms. (3) The byproduct of the growth of bacteria or organisms in decomposing material (including the food substance itself), or waste, in food or water.

CONTAMINATION AVOIDANCE – Individual or unit measures taken to avoid or minimize NBC attacks and reduce the effects of NBC hazards. Passive contamination avoidance measures are concealment, dispersion, deception, and the use of cover to reduce the probability of the enemy using NBC weapons on your units and minimize damage caused by NBC weapons if they are used. Active contamination avoidance measures are: contamination control; detection, identification, and marking of contaminated areas; issuance of contamination warnings; and relocation or rerouting to an uncontaminated area.

CONTAMINATION, RADIOACTIVE – The presence of radioactive materials where it is not desired, particularly where its presence may be harmful.

COSMIC RAYS – Radiation that originates from sources outside the earth's atmosphere and which contributes to the natural background radiation present in man's environment.

CRITICAL MASS – The minimum mass of a fissionable material that will just maintain a fission chain reaction under precisely specified conditions, such as the nature of the material and its purity, the nature and thickness of the tamper (or neutron reflector), the density (or compression), and the

physical shape (or geometry). For an explosion to occur, the system must be supercritical; i.e., the mass of material must exceed the critical mass under the existing conditions.

DECAY – Spontaneous decrease in the number of radioactive atoms in radioactive material, by the emission of particle or rays from the atom's nucleus.

DECAY PRODUCT – A nuclide resulting from the radioactive disintegrations of a radionuclide, formed either directly or as a result of successive transformations in a radioactive series.

DECONTAMINATION (CHEMICAL AND BIOLOGICAL) – Process of making any person, object, or area safe by absorbing, destroying, neutralizing, or removing chemical agents or biological agents.

DECONTAMINATION (NUCLEAR) – The reduction or removal of contaminating radioactive material from a structure, area, equipment, or person. Decontamination may be accomplished by: (1) treating the surface so as to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of its natural decay; and (3) covering the contamination so as to attenuate or reduce the radiation emitted.

DELIBERATE DECON – Operations or techniques intended to decontaminate clothing and equipment so operators or crew members can perform their mission with individual and respiratory protection removed.

DETECTION – Discovery, identification, and marking of contaminated areas. Detection is the act of finding out by use of chemical detectors or radiological survey instruments the location of NBC hazards placed by the enemy. Detectors and instruments are normally operated by NBC monitoring/ survey teams.

DISINTEGRATION – Process of spontaneous breakdown of a nucleus resulting in the emission of a particle and/or a photon.

DOSE – A general term denoting the quantity of radiation or energy absorbed. For special purposes it must be appropriately qualified. If unqualified, it refers to absorbed dose. (See absorbed dose).

DOSE RATE – Absorbed dose delivered per unit time (cGy/hour).

DOSIMETER – Instrument to detect and measure accumulated radiation exposure. The tactical dosimeter is a pencil–size ionization chamber with a self–reading electrometer used for personnel monitoring (IM–93).

ELECTRON – A particle of very small mass, carrying a negative charge of one. Electrons surround the nucleus in all neutral atoms.

ELECTRON VOLT (eV) A small unit of energy equivalent o the energy gained by one electron in passing through a potential difference of 1 volt.

ENERGY – The ability to do work.

ERYTHEMA – An abnormal redness of the skin, due to an excess of blood in the capillaries, caused by a variety of agents, including ionizing radiation.

EXPOSURE – A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the "roentgen." Abbreviated (R).

FALLOUT – The radioactive debris, usually from a nuclear detonation, which is deposited on the earth's surface after having been airborne. Local (or early) fallout is defined, somewhat arbitrarily, as those particles which reach the earth within 24 hours after a nuclear explosion. Worldwide (or delayed) fallout consists of the smaller particles which ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the earth. The worldwide fallout is brought to earth, mainly by rain and snow, over extended periods ranging from months to years. Fallout emits beta and gamma radiation. (See residual radiation).

FIREBALL – The luminous sphere of hot gases formed by a nuclear explosion.

FISSION – A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

FISSIONABLE – Refers to isotopes (uranium 235, plutonium 239) which can be made to undergo fission easily.

FISSION FRAGMENT – One of the unstable by–products of the fission process. (See fission products, below).

FISSION PRODUCTS – A general term for the complex mixture produced as a result of nuclear fission. A distinction should be made between these and the fission fragments. Something like 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species (e.g., 235U or 239Pu). The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains about 200 different radioisotopes which are either pure beta emitters or beta–gamma emitters.

FLASH TO BANG TIME – The elapsed time between the emission of the bright light and the arrival of the blast wave (or sound) of a nuclear detonation. Each 3 seconds of flash to bang time corresponds to approximately 1 kilometer of range.

FLASH BURN – A burn caused by excessive exposure to the radiated heat from the fireball of a nuclear explosion.

FUSION – The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen (deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial amounts of energy.

GAMMA RADIATION – Electromagnetic radiation originating from the nucleus of an atom.

GEIGER–MUELLER (G–M) SURVEY METER – An instrument consisting of a gas filled Geiger–Mueller tube as the detecting element and accompanying electronic circuitry to measure low levels of Beta–Gamma radiation. (AN/PDR–27)

GENETIC EFFECT – With respect to radiation exposure, that damage which affects the material in the cell associated with reproduction and heredity. By definition those effects which appear in future generations of the organism irradiated.

GRAY (Gy) – Unit of absorbed dose of ionizing radiation equal to 100 rad or 1 Joule/Kg.

GROUND ZERO (GZ) – The point on the earth's surface vertically below or above the center of burst of a nuclear weapon.

GUN–TYPE WEAPON (OR GUN–ASSEMBLY WEAPON) – A device in which two or more pieces of fissionable material, each in a subcritical state, are brought together very rapidly so as to form a supercritical mass which can explode as the result of a rapidly expanding fission chain reaction.

H – H represents H–hour, the time of detonation. Time after detonation is expressed in hours unless otherwise specified. For example H + 2 refers to the time two hours after detonation of a particular nuclear weapon.

HALF–LIFE, RADIOACTIVE – Time required for 50 percent of the nuclei of radioisotope (radionuclide) to disintegrate.

HALF–VALUE LAYER (HVL) – The thickness of a specified material which, when placed in the path of a given beam of X–ray or gamma radiation, reduces the exposure rate by one–half.

HASTY DECON – Action of teams or squads using equipment found within battalion sized units to reduce the spread of contamination on people or equipment and allow temporary relief from MOPP 4.

HOB – (Height of Burst) The vertical distance in feet above the surface.

ILLUMINATION TIME – The period of time during which the fireball from a nuclear detonation emits a bright light.

IMPLOSION–TYPE WEAPON (IMPLOSION WEAPON) – A device in which a quantity of fissionable material, in a subcritical state, has its volume suddenly decreased by compression so that it becomes supercitical and explodes. The compression is achieved by means of a spherical arrangement of specially

fabricated shapes of ordinary high explosive which produce an inwardly directly implosion wave. The fissionable material, being at the center of the sphere, is thereby compressed to a supercritical state.

INDUCED RADIOACTIVITY – Radioactivity produced in previously nonradioactive materials as a result of nuclear reactions, particularly the capture of neutrons.

INITIAL RADIATION – Nuclear radiation, essentially neutrons and gamma radiation, emitted from the fireball and the cloud column during the first minute after nuclear detonation.

ION – An atom or molecule that has lost or gained one or more electrons by ionization thereby acquiring an electrical charge.

IONIZATION – The process by which a neutral atom or molecule acquires a negative or positive charge.

IONIZING RADIATION – Any radiation capable of removing electrons from an atom either directly or indirectly leaving a positively charged ion.

ION PAIR – A closely associated positive ion and negative ion having opposite charges of the same magnitude.

IRRADIATION – Exposure to radiation.

ISOTOPE – Nuclides having equal numbers of protons and thus with identical chemical properties but different numbers of neutrons and therefore dissimilar nuclear properties.

KILOTON (KT) – Refers to the energy released by the detonation of 1,000 tons of TNT. Normally the energy equivalent of nuclear detonations is expressed as KT.

LASER – Light amplification by stimulated emission of radiation.

LATENT PERIOD – During the acute radiation syndrome, that period of time between the end of the initial effects (prodrome) and the onset of the secondary illness, during which the individual appears to recover.

MACH STEM – A reinforcement of the shockwave front by the reflected shock-wave from the surface.

MARK I (NAAK) – Nerve Agent Antidote Kit

MASS – The material equivalent of energy—differs from weight in that it neither increases nor decreases with gravitational force.

MEGATON (MT) – Refers to the equivalent energy release from the explosion of a million tons of TNT. (See Kiloton, above; and TNT equivalent, below).

MONITORING – Periodic or continuous measuring of the dose rate from radio-

active contamination.

MOPP – Mission–oriented protective posture. A flexible system that provides maximum NBC protection for the individual with the lowest risk possible and still allow mission accomplishment.

NBC – Nuclear, Biological, and Chemical

NBCC – Nuclear, biological, and chemical center. The division NBCC plans for and directs the collection effort for NBC hazards information.

NBCWRS – Nuclear, biological and chemical warning and reporting system. Units use the NBCWRS as battlefield intelligence to send and receive NBC 1–6 reports.

NEUTRON – An uncharged nuclear particle with a mass approximately equal to that of a hydrogen atom.

NONEFFECTIVE – As applied to an individual, one who cannot perform his assigned mission or task.

NONPERSISTENT AGENT – A chemical agent that – when released – dissipates or loses its ability to cause casualties after 10 to 15 minutes.

NUCLEAR RADIATION – Electromagnetic and particulate ionizing radiations which originate in the nucleus.

NUCLEAR REACTION – A process involving a change in the nucleus, such as fission, fusion, neutron capture or radioactive decay. It is distinct from a chemical reaction which is limited to changes in only the electron structure surrounding the nucleus.

NUCLEAR REACTOR – An assembly of nuclear fuel capable of sustaining a controlled chain reaction based on nuclear fission: sometimes called a pile.

NUCLEAR WEAPON (ATOMIC BOMB) – A general name given to any weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both. Thus the A–(or atomic) bomb and the H–(or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since it is energy of the atomic nuclei that is involved in each case. However, it has become more or less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A–bombs or atomic bombs. To make a distinction, those weapons in which part, at least, of the energy results from thermonuclear (fusion) reactions among the isotopes of hydrogen have been called H–bombs or hydrogen bombs.

NUCLEUS – The heavy central part of an atom in which most of the mass and the total positive electric charge is concentrated.

NUCLIDE – A general term referring to all nuclear species, both stable and

unstable, of the chemical elements, as distinguished from the two or more nuclear species of a single chemical element which are called "isotopes."

OVERPRESSURE – The transient pressure usually expressed in pounds per square inch (psi), exceeding existing (ambient) atmospheric pressure and manifested in the shock or blast wave from an explosion.

PEAK OVERPRESSURE – The highest overpressure resulting from the blast wave.

PERSISTENT AGENT – A chemical agent that – when released – remains in an area from hours to days releasing vapors and not losing its ability to cause casualties.

PETECHIAE – Small, pinpoint, nonraised, round purplish–red spots caused by intradermal or submucosal hemorrhage, which later turn blue or yellow.

PHOTON – A quantity or "bundle" of electromagnetic energy, usually x or gamma radiation.

POSITRON – A positively charge particle equal in mass to the electron.

PRODROME – The prodrome represents the initial effects from an acute exposure to radiation, onset and length of time and severity are dose dependent.

PROTON (p) – A nuclear particle with a positive electric charge of one. Its mass is approximately equal to that of a neutron.

PURPURA – Large hemorrhagic spots in or under the skin or mucosal tissues.

QF (QUALITY FACTOR) – A factor which is a function of linear energy transfer. It relates absorbed dose to dose equivalent (rads to rem) (or Gy to Sv) in radiation protection.

RADIAC – A term devised to designate various type of radiological measuring instruments. (Acronym: Radioactivity Detection Indication And Computation).

RADIATION (IONIZING) – Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, by interaction with matter.

EXTERNAL RADIATION – Radiation from a source outside the body.

INTERNAL RADIATION – Radiation from radioactivity deposited within the body.

RADIATION PROTECTION OFFICER (RPO) – The person designated by the commander as responsible for the radiation protection program.

RADIATION PROTECTION STANDARDS – Radiation doses which should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below these guides as possible.

RADIOACTIVITY – The property of certain unstable nuclides to spontaneously emit particles or gamma radiation or to emit X–radiation following orbital electron capture or to undergo spontaneous fission.

RADIOISOTOPE – An unstable isotope that decays or disintegrates spontaneously, emitting radiation.

RADIUS OF EFFECT – The maximum distance from ground zero at which a specific nuclear weapon effect occurs.

RANGE (NUCLEAR WEAPON EFFECTS) – The horizontal distance from ground–zero to which a given weapon effect extends.

REM (ROENTGEN EQUIVALENT MAN) – The unit of dose equivalent which is the product of the dose in cGy and an appropriate modifying factor such as QF (radiation protection).

RESIDUAL NUCLEAR RADIATION – Nuclear radiation, chiefly beta particles and gamma rays, which persist for some time following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residue in the fallout, and to some extent by earth and other materials in which radioactivity has been induced by the capture of neutrons.

ROENTGEN (R) – The unit of exposure of X or gamma radiation in air.

SECONDARY BLAST INJURIES – Those injuries sustained from the indirect blast effects, such as from rubble from a collapsed building or from missiles (debris or objects) which have been picked up by the winds generated and hurled against an individual. Also includes injuries resulting from individuals being hurled against stationary objects. (Sometimes referred to as tertiary effect.)

SECONDARY ILLNESS – The manifest illness phase of acute radiation injury which takes on the signs and symptoms associated with injury to the critical organ system.

SHIELD – A material used to prevent or reduce the passage of radiation.

SOMATIC EFFECTS OF RADIATION – A general term for all effects caused or induced by ionizing radiation which manifest themselves during the lifetime of the individual receiving the radiation dose (as opposed to genetic effects).

STABLE ISOTOPE – An isotope that does not undergo radioactive decay.

SUPERCRITICAL – The term applied to fissionable material which has been altered from the critical state (by a change in its mass, density, or shape, or by tamping) to a condition in which the neutrons produced inside the material increase rapidly and uncontrollably to produce a nuclear explosion. The number of fissions increase geometrically, and the neutrons produced there by will sustain an increasing or multiplying chain reaction.

SURVEY METER – Any portable radiation detection instrument especially adapted

for surveying or monitoring an area, structure, personnel, clothing, or equipment to establish the existence and amount of radioactive material present.

SYMPTOM – Any functional evidence of disease or of a patient's condition.

SYNDROME – A set of symptoms which occur together.

TAMPER – Material surrounding the fissionable material in a nuclear weapon for the purpose of holding the supercritical assembly together by its inertia and for reflecting neutrons, thus increasing the number of fissions in the active material.

THERMAL RADIATION – Electromagnetic radiation emitted from the fireball as a consequence of its very high temperature. It consists essentially of ultraviolet, visible, and infrared radiation.

THERMONUCLEAR (THERMONUCLEAR WEAPONS) – An adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes (deuterium and tritium), with the accompanying liberation of energy. A thermonuclear bomb is a weapon in which part of the explosion energy results from thermonuclear fusion reactions. The high temperatures required may be obtained by means of a fission explosion.

THERMONUCLEAR BOMB (DEVICE) – A hydrogen bomb.

TNT EQUIVALENT – A measure of the energy released in the detonation of a nuclear explosive expressed in terms of the weight of TNT which would release the same amount of energy when exploded. It is usually expressed in kilotons or megatons. The TNT equivalence relationship is based on the fact that 1 ton of TNT releases 1 billion calories of energy.

UNSTABLE ISOTOPE – A radioisotope.

WEAPON EFFECTS – The damage or casualty producing agents, specifically blast, thermal radiation, and nuclear radiation, resulting from a nuclear explosion.

WEAPONS SYSTEM – The combination of the weapon (or warhead), the fire control system, and the carrier.

X–RAYS – Short wavelength electromagnetic radiation identical to gamma radiation, but its origin is in the electron shell of the atom. (See gamma radiation).

YIELD (OR ENERGY YIELD) – The total effective released in a nuclear (or atomic) explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. See: TNT equivalent.

ZONE I (NUCLEAR) – That fallout area downwind from a nuclear detonation where

troops may receive 150 cGy or more within 4 hours after the arrival of fallout.

ZONE I (BIOLOGICAL) – The area in which casualties among unprotected personnel will be high enough (greater than 20%) to cause significant disruption, disability, or elimination of unit operations of effectiveness.

ZONE II (NUCLEAR) – The fallout area where troops may receive 50 cGy or more in 24 hours after the arrival of fallout.

ZONE II (BIOLOGICAL) – That area downwind from a biological agent release when hazards to unprotected personnel are likely to exceed negligible risk levels (1 – 3% casualties) under an aerosol disseminated attack. This zone may be very large; under some conditions encompassing thousands of square kilometers.

CORRESPONDENCE COURSE OF
THE ACADEMY OF HEALTH SCIENCES, U.S. ARMY

EXAMINATION

SUBCOURSE MED447	--Medical Aspects of Nuclear Weapons and Their Effects on Medical Operations.
CREDIT HOURS	--21.
TEXT ASSIGNMENT	--Subcourse MED447.
MATERIALS REQUIRED	--You may use the text furnished with this subcourse in accomplishing this examination.
SUGGESTION	--Check to see that your computerized answer sheet is for edition 0 of Subcourse MED447. Inform Extension Services Division, AHS, of any mismatch so that you will receive the correct grade.

THIS EXAMINATION CONTAINS 50 ITEMS

REQUIREMENT. Each of the following questions or incomplete statements is followed by a group of lettered responses. Select the ONE response that BEST answers the question or completes the statement. On the answer sheet, blacken the space corresponding to the letter of your choice.

Examination questions 1 through 5 are matching questions. Match the column A items with the appropriate column B option.

Column A		Column B	
1.	Gy.	a.	IM-93UD.
2.	AN/PDR-27.	b.	Nerve Agent Antidote Kit.
3.	Mark I.	c.	Flexible system that provides maximum NBC protection for the individual and still allows mission accomplishment.
4.	MOPP.		
5.	Dosimeter.	d.	Used to measure Beta-Gamma radiation.
		e.	Unit of absorbed dose of ionizing radiation equal to 100 rad.

6. In the atom of uranium, $^{238}_{92}U$, there are _____ protons, _____ neutrons, and _____ nucleons, respectively.

a. 238, 146, and 92.

b. 92, 146, and 238.

c. 146, 92, and 238.

d. 330, 238 and 146.

7. The symptoms of the prodromal phase of the hematopoietic and gastrointestinal forms of acute radiation syndrome are about the same except that the symptoms of the gastrointestinal form are more:

a. Severe and more rapidly appearing.

b. Characteristic of acute infection or septicemia.

c. Likely to include a longer latent period.

d. Easily distinguished from those of the central nervous system form.

8. If a person absorbed a whole body, acute, ionizing radiation dose of over 3,000 rad, his first obvious symptoms of radiation sickness would be those of the _____form of the acute radiation syndrome.

a. Hematopoietic.

b. Gastrointestinal.

c. Cerebral.

9. For medical planning purposes, about how long after a nuclear attack will the major portion of those injured in a target city have to get along without organized medical help?

a. 1 day.

b. 3 days.

c. 20 days.

d. 60 days.

10. In the management of mass casualties, there will be great disparity between the extent of the problem and medical means to solve it. This disparity exists in three main areas. All of the following, EXCEPT that in choice _____ depict these areas.

a. The fear of people to become involved.

b. The enormous workload.

c. Necessary supplies and medical facilities in short supply.

d. Lack of trained personnel.

11. Under disaster conditions, which of the following tasks may be performed by an MSC officer for patients who are in need of the services listed?

a. Assisting in major surgery.

b. Performance of circulating nurse duties.

c. Rendering preoperative and postoperative care.

d. Establishment of an emergency airway.

12. Immediately following a nuclear explosion, casualties should be sorted into four categories for treatment, evacuation, or return to duty. What category of patients should given first priority?

a. Immediate.

b. Expectant.

c. Delayed.

d. Minimal.

13. In a nuclear weapons detonation, the greatest percentage of released energy is in the form of:

a. Blast or shock wave.

b. Thermal radiation.

c. Nuclear radiation.

14. What probable effects will be caused by exposure to an acute dose of 100 rad or less in 24 hours of either initial or residual nuclear radiation?

a. Immediate death.

b. CNS form of radiation illness.

c. No clinical evidence of disease.

d. Nausea and vomiting with blood changes.

15. Which of the following blasts produces fallout?

a. Airburst.

b. Surface burst.

c. Subsurface burst.

16. A burn which is characterized by blister formation is a _____ degree burn.

a. First.

b. Second.

c. Third.

17. Which of the following factors has (have) any effect on the amount of thermal radiation from a nuclear weapon detonation?

a. Weapon size.

b. Altitude of detonation of the weapon.

c. Atmospheric conditions.

d. All of the above.

18. What is one limiting factor in the use of experience gained from patients who have been treated successfully with clinical radiotherapy?

a. The number of cases is too small.

b. The cases are poorly documented.

c. The treatments had little, if any, whole body effects.

d. The doses were larger than those which might be encountered under warfare conditions.

19. The time period after the onset of a mass casualty situation is divided into four phases. Phase II involves:

a. 3 days.

b. From 3 to 20 days.

c. From 20 to 60 days.

d. 60 days and more.

20. Which of the following is the most sensitive to the acute radiation injury?

a. Parenchymal cells of liver and kidney.

b. Nerve cells.

c. Muscle cells.

d. Bone marrow.

21. What is the probable range of absorbed dose for the classification of hematopoietic form of the acute radiation syndrome?

a. 0 – 100 rad.

b. 200 – 800 rad.

c. 800 – 3000 rad.

d. 3000 rad and up.

22. In the classification of the acute radiation syndrome which follows irradiation, certain assumptions are made. All of the following, EXCEPT that in choice_____ are valid assumptions for the discussion in the Subcourse.

a. There has been no significant prior or concomitant injury.

b. The body is uniformly irradiated.

c. The individual is average.

d. All doses are received over a considerable period of time.

23. What is the probable range of absorbed dose, if any, for the disease classification of "No obvious disease"?

a. There is no absorbed radiation.

b. 0 to 100 rad.

c. 200 – 500 rad.

d. 500 – 1000 rad.

24. The typical hematopoietic form of the acute radiation syndrome is characterized by all of the phases below, EXCEPT that in choice _____.

a. Gastrointestinal.

b. Prodromal.

c. Latent.

d. Bone marrow depression.

e. Recovery.

25. During which phase of the acute hematopoietic syndrome should you expect to see epilation?

a. Prodromal.

b. Latent.

c. Bone marrow depression.

d. Recovery.

e. None of the above.

26. All of the following, EXCEPT that in choice _____ are initial symptoms of the prodromal phase of the acute hematopoietic syndrome.

a. Fatigue.

b. Lethargy.

c. Anorexia.

d. Diarrhea.

27. You are 900 meters away from a 10 KT nuclear weapons detonation (surface burst) in an exposed location. What degree of thermal burns would you expect?

a. First.

b. Second.

c. Third.

28. Which of the following results would you expect from a 10 KT weapon, low airburst, if you were 1000 meters away from ground zero? Severe damage to:

a. An adjacent brick apartment house.

b. Foxholes.

c. Oil storage tanks.

d. Underground bunkers.

29. You are in an exposed location when you see the reflected illumination from a nuclear weapons detonation. The illumination lasts about 9 seconds. The yield of this weapon is about _____ KT.

a. 125.

b. 160.

c. 200.

d. 475.

30. Which of the following "paints" a true picture of the bone marrow depression phase of the acute hematopoietic syndrome?

a. Hemorrhagic fever.

b. Lymphopenia.

c. Acute aplastic anemia.

d. Leukocytosis.

31. You are in a foxhole when there is an outside reading for residual radiation of 500 rad/hr. What is the rate inside the foxhole?

a. 450 rad/hr.

b. 250 rad/hr.

c. 50 rad/hr.

d. 5 rad/hr.

32. Which of the following choices describes the gamma ray?

a. A particle of electromagnetic radiation originating from the nucleus of an atom with energy from 10 keV to approximately 20 MeV.

b. The negatively charged particle surrounding the nucleus of an atom.

c. The unit of absorbed dose of any ionizing radiation.

d. A nuclear particle with a charge which is electrically neutral and with a mass approximately equal to that of a hydrogen atom.

33. Which of the following field radiac equipment is used to survey an area for gamma dose rate in a range of 0 to 500 rad/hr?

a. IM 9/PD.

b. IM 174A/PD.

c. IM 93/UD.

d. IM 147/PD.

34. If you have an effective wind speed of 20 kmph and a yield of 100 KT, the downwind distance of Zone I for a surface burst would be about:

a. 13 km.

b. 35 km.

c. 45 km.

d. 90 km.

35. In the plan recommended by the American Medical Association for providing organized medical care under disaster conditions, what will be the role of each paramedical worker?

a. To perform his regular patient care tasks for a larger number of patients.

b. To perform tasks ordinarily reserved for one of higher professional license in patient care and treatment.

c. To supervise untrained personnel in the performance of all medical care tasks.

d. To develop instructional materials for use in case of disaster.

36. If the radiation dose rate at H + 1 is 4,500 rad/hr, what will be the dose rate at H + 7?

a. 450.

b. 400.

c. 250.

d. 125.

37. If the radiation dose rate at H + 1 is 600 rad/hr, what will the dose rate be at H + 2?

a. 370.

b. 350.

c. 300.

d. 270.

38. Which of the three methods used in calculating doses and dose rates is the least accurate method?

a. ABC-M1 Radiac Calculator.

b. Rules of thumb.

c. Nomograms.

39. Of what would the treatment for patients in the expectant category consist?

a. Resuscitation and as much emergency medical treatment as facilities, supplies, and professional personnel permit.

b. Delayed treatment with possible complications resulting but no jeopardy to life.

c. Relatively short procedures.

d. Minimum treatment with return to duty.

40. In a mass casualty situation, the patients falling into the minimal category would be about_____ percent of the total patient load.

a. 20.

b. 30.

c. 40.

d. 50.

41. In a mass casualty situation, patients who have open fractures of major bones will be placed in the _____ category.

a. Immediate.

b. Minimal.

c. Delayed.

d. Expectant.

42. In a mass casualty situation, a typical sorting team is composed of:

a. A physician, a dental officer, and 12 to 15 medical specialists.

b. Two physicians, 3 dental officers, and 2 to 3 medical specialists.

c. Three physicians, 2 dental officers, and 4 or 5 medical specialists.

d. All available physicians, dental officers, nurses, veterinarians, and medical specialists.

43. It is now 1600 hours, Greenwich Mean Time. What time is it in San Antonio, Texas?

a. 1600 hours.

b. 1200 hours.

c. 1000 hours.

d. 0800 hours.

44. Refer to the map and overlay. Which of the following units is outside of both Zone I and Zone II?

a. Hq, 36th Inf Div.

b. 1st Bn, 504th Armor.

c. 36th DISCOM.

d. 98th Combat Support Hospital.

45. In the map exercise, how was the 6 km distance from the Engineer Bn to GZ found?

a. From the illumination time.

b. From the Effective Downwind Message.

c. From the flash-to-bang time.

d. None of the above.

Examination questions 46 through 50 are matching questions. Match the column A items with the appropriate column B option.

Column A		Column B	
46.	100 rad or less in 24 hours.	a.	50% require MEDVAC in less than 24 hours.
47.	More than 300 rad delivered in less than an hour.	b.	90% vomiting in 6 hours.
48.	500–1000 rad in 24 hours.	c.	No evacuation for temporary illness.
49.	350–450 rad gradually over 1 year.	d.	Decreased efficiency and increased susceptibility to trauma and late effects.
50.	100–200 rad in less than 24 hours.	e.	No ineffectiveness.

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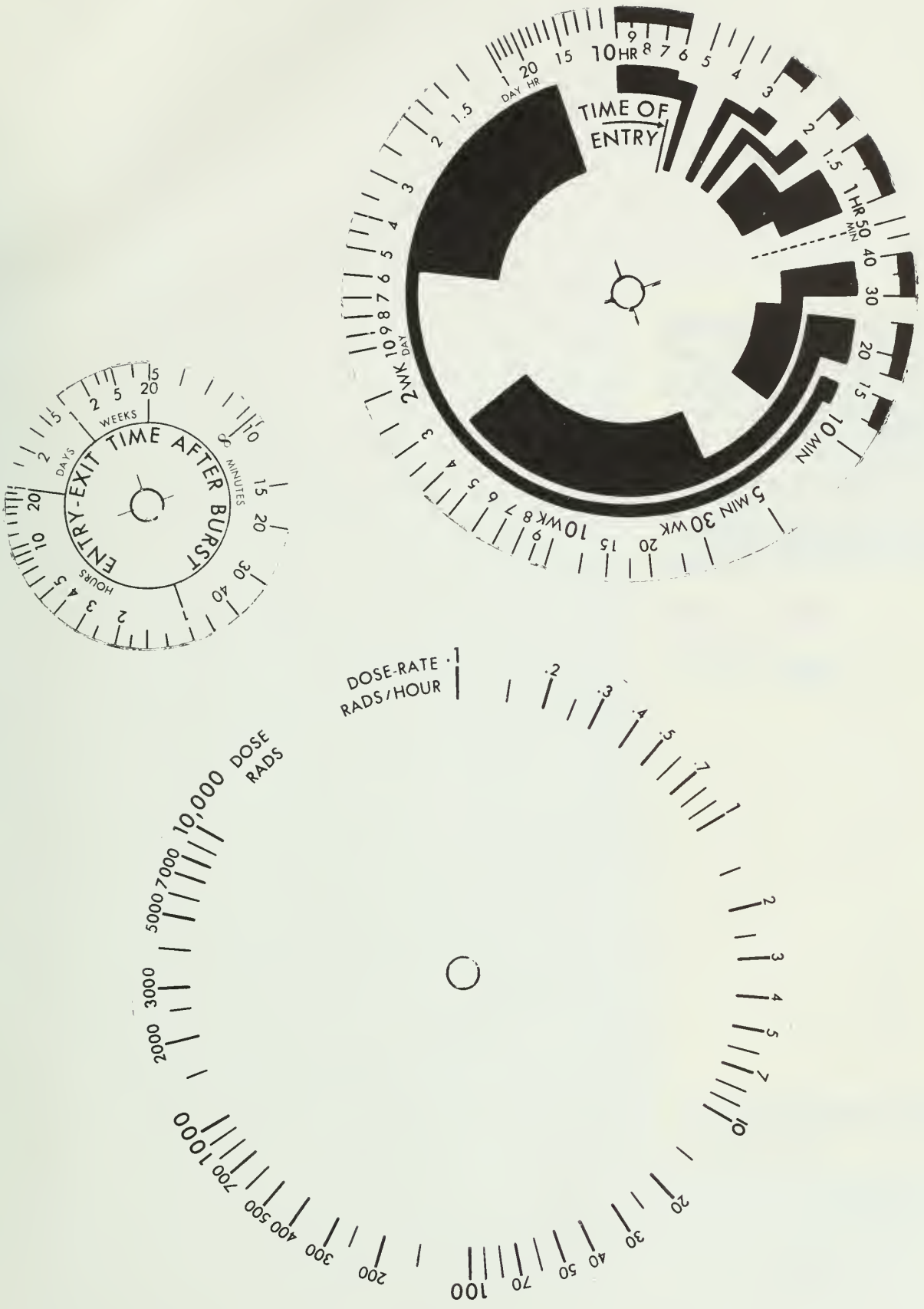

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